9TH CLASS

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PHYSICAL QUANTITIES AND MEASUREMENT

STUDENTS LEARNING OUTCOMES

[illegible] unit, the students will be [illegible]

- describe the crucial role of Physics in Science, Technology and Society.
- explain with examples that Science is based on physical quantities which consist of numerical magnitude and a unit.
- differentiate between base and derived physical quantities.
- list the seven units of System International (SI) along with their symbols and physical quantities (standard definitions of SI units are not required).
- interconvert the prefixes and their symbols to indicate multiple and sub-multiple for both base and derived units.
- write the answer in scientific notation in measurements and calculations.
- describe the working of Vernier Callipers and screw gauge for measuring length.
- identify and explain the limitations of measuring instruments such as metre rule, Vernier Callipers and screw gauge.
- describe the need using significant figures for recording and stating results in the laboratory.

[illegible]

This unit is built on:

Measurement	**–Science-VIII**
Scientific Notation	**–Maths-IX**

This unit leads to:

Measurement	**–Physics-XI**

INVESTIGATION SKILLS

- compare the least count/ accuracy of the following measuring instruments and state their measuring range:
  (i) Measuring tape (ii) Metre rule
  (iii) Vernier Callipers
  (iv) Micrometer screw gauge
- make a paper scale of given least count, e.g. 0.2cm and 0.5cm.
- determine the area of cross section of a solid cylinder with vernier callipers and screw gauge and evaluate which measurement is more precise.

Major concepts

1.1 Introduction to Physics
1.2 Physical quantities
1.3 International system of units
1.4 Prefixes (multiples and sub-multiples)
1.5 Scientific notation/ Standard form
1.6 Measuring instruments
- metre rule
- vernier callipers
- screw gauge
- physical balance
- stop watch
- measuring cylinder

1.7 An introduction to significant figures

- determine an interval of time using stopwatch.
- determine the mass of an object by using different types of balances and identify the most accurate balance.
- determine volume of an irregular shaped object using a measuring cylinder.
- List safety equipments and rules.
- use appropriate safety equipments in the laboratory.

SCIENCE, TECHNOLOGY AND SOCIETY CONNECTION

- determine length, mass, time and volume in daily life activities using various measuring instruments.
- list with brief description the various branches of physics.

Q 1. How physical quantities and measurement are connected with science, technology and society?

Ans: Man has always been inspired by the wonders of nature. He has always been curious to know the secrets of nature and remained in search of the truth and reality. He observes various phenomena and tries to find their answers by logical reasoning. The knowledge gained through observations and experimentations is called **Science**. The word science is derived from the Latin word **scientia**, which means knowledge. Not until eighteenth century, various aspect of material objects were studied under a single subject called **natural philosophy**. But as the knowledge increased, it was divided into two main streams: Physical sciences _ Which deal with the study of non-living things and Biological sciences _ which are concerned with the study of living things.

> Interesting information
>
> **When you can measure what you are speaking about and express it in numbers, you know something about it. When you cannot measure what you are speaking about or you cannot express it in numbers, your knowledge is of a meagre and of unsatisfactory kind.**
>
> Lord Kelvin

Measurements are not confined to science. They are part of our lives. They play an important role to describe and understand the physical world. Over the centuries, man has improved the methods of measurements.

> FOR YOUR INFORMATION
>
> Andromeda is one of the billions of galaxies of known universe.

1.1 Introduction to Physics

Q2. (a) In the nineteenth century, into how many disciplines physical sciences were divided?

(b) Define Physics. Write importance of physics in daily life.

Ans. (a) In the nineteenth century, physical sciences were divided into five distinct disciplines.

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السلام علیکم ورحمۃ اللہ وبرکاتہ:

معزز ممبران: آپ کا وٹس ایپ گروپ ایڈمن "**اردو بکس**" آپ سے مخاطب ہے۔

آپ تمام ممبران سے گزارش ہے کہ:

- گروپ میں صرف PDF کتب پوسٹ کی جاتی ہیں لہذا کتب کے متعلق اپنے کمنٹس / ریویوز ضرور دیں۔ گروپ میں بغیر ایڈمن کی اجازت کے کسی بھی قسم کی (اسلامی وغیر اسلامی، اخلاقی، تحریری) پوسٹ کرنا سختی سے منع ہے۔
- گروپ میں معزز، پڑھے لکھے، سلجھے ہوئے ممبرز موجود ہیں اخلاقیات کی پابندی کریں اور گروپ رولز کو فالو کریں بصورت دیگر معزز ممبرز کی بہتری کی خاطر ریموو کر دیا جائے گا۔
- کوئی بھی ممبر کسی بھی ممبر کو انباکس میں میسج، مس کال، کال نہیں کرے گا۔ رپورٹ پر فوری ریموو کرکے کاروائی عمل میں لائے جائے گی۔
- ہمارے کسی بھی گروپ میں سیاسی و فرقہ واریت کی بحث کی قطعاً کوئی گنجائش نہیں ہے۔
- اگر کسی کو بھی گروپ کے متعلق کسی قسم کی شکایت یا تجویز کی صورت میں ایڈمن سے رابطہ کیجئے۔
- سب سے اہم بات:

گروپ میں کسی بھی قادیانی، مرزائی، احمدی، گستاخِ رسول، گستاخِ امہات المؤمنین، گستاخِ صحابہ و خلفائے راشدین حضرت ابو بکر صدیق، حضرت عمر فاروق، حضرت عثمان غنی، حضرت علی المرتضیٰ، حضرت حسنین کریمین رضوان اللہ تعالیٰ اجمعین، گستاخ اہلبیت یا ایسے غیر مسلم جو اسلام اور پاکستان کے خلاف پراپیگنڈا میں مصروف ہیں یا ان کے روحانی و ذہنی سپورٹرز کے لئے کوئی گنجائش نہیں ہے لہذا ایسے اشخاص بالکل بھی گروپ جوائن کرنے کی زحمت نہ کریں۔ معلوم ہونے پر فوراً ریموو کر دیا جائے گا۔

- تمام کتب انٹرنیٹ سے تلاش / ڈاؤنلوڈ کر کے **فری آف کاسٹ** وٹس ایپ گروپ میں شیئر کی جاتی ہیں۔ جو کتاب نہیں ملتی اس کے لئے معذرت کر لی جاتی ہے۔ جس میں محنت بھی صَرف ہوتی ہے لیکن ہمیں آپ سے صرف دعاؤں کی درخواست ہے۔
- عمران سیریز کے شوقین کیلئے علیحدہ سے عمران سیریز گروپ موجود ہے۔
- **لیڈیز کے لئے الگ گروپ کی سہولت موجود ہے جس کے لئے ویریفکیشن ضروری ہے۔**
- اردو کتب / عمران سیریز یا سٹڈی گروپ میں ایڈ ہونے کے لئے ایڈمن سے وٹس ایپ پر بذریعہ میسج رابطہ کریں اور جواب کا انتظار فرمائیں۔ برائے مہربانی اخلاقیات کا خیال رکھتے ہوئے موبائل پر کال یا ایم ایس کرنے کی کوشش ہر گز نہ کریں۔ ورنہ گروپس سے تو ریموو کیا ہی جائے گا بلاک بھی کیا جائے گا۔

نوٹ: ہمارے کسی گروپ کی کوئی فیس نہیں ہے۔ سب فی سبیل اللہ ہے

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اللہ تبارک تعالیٰ ہم سب کا حامی و ناصر ہو

1. Physics 2. Chemistry 3. Astronomy 4. Geology 5. Meteorology

(b) Physics: Physics is the most fundamental discipline in physical sciences. In Physics matter, energy and their interaction are studied. The laws and principles of physics help us to understand nature.

Importance of physics in daily life: Most of the technologies of our modern society throughout the world are related to Physics.

In our daily life, we hardly find a device where physics is not involved.

DO YOU KNOW?

Wind turbines are used to produce pollution free electricity.

1. A car is made on the principles of mechanics.
2. A refrigerator is based on the principles of thermodynamics.
3. A pulley makes easy to lift heavy loads.
4. Electricity is used not only to get light and heat but also mechanical energy that drives fans and electric motor etc.
5. Consider the means of transportation such as car and aeroplanes are the applications of physics.
6. Domestic appliances such as air-conditioners, refrigerators, vacuum-cleaners, washing machines, and microwave ovens etc. are the applications of physics

Figure 1.1: (b) A vacuum cleaner

7. Means of communication such as radio, TV, telephone and computer are the results of applications of physics.
8. Mobile phone allows us to contact people anywhere in the world and to get latest worldwide information. It is used to save pictures, send and receive messages. It can also receive radio transmission and can use it as a calculator as well.

(c) a mobile phone

Advantages of scientific discoveries: Above all devices have made our lives much easier, faster and more comfortable than the past.

Disadvantages of scientific discoveries:

The scientific discoveries have also caused harms and destruction of serious nature. One of which is environmental pollution and other is deadly weapons.

Quick Quiz.

1. Why do we study physics?

Ans: We study physics because Physics is the branch of science which deals with the matter, energy and their interaction. Most of the technologies of our modern society throughout the world are related to physics. In our daily life, we hardly find a device where physics is not involved.
These all discoveries made our lives much easier, faster and more comfortable.

2. Name any five branches of Physics.

Ans: 1. Mechanics 2. Thermodynamics 3. Electromagnetism 4. Atomic Physics 5. Plasma Physics

Q3. What are the important branches of physics. Define them.

Ans: Important branches of physics can be defined as following.

BRANCHES OF PHYSICS:

Mechanics:

This branch of physics is the study of motion of objects, its causes and effect.

Heat: This branch of physics deals with the nature of heat, modes of transfer and effects of heat.

Sound: It deals with the physical aspects of sound waves, their production, properties and applications.

Light (Optics): It is the study of physical aspects of light, its properties; working and use of optical instruments.

Electricity and Magnetism: It is the study of the charges at rest and in motion, their effects and their relationship with magnetism.

Atomic Physics: It is the study of the structure and properties of atoms.

Nuclear physics: It deals with the properties and behaviour of nuclei and the particles within the nuclei.

Plasma Physics: It is the study of production, properties of the ionic state of matter-the fourth state of matter.

Geophysics: It is the study of the internal structure of the Earth.

1.2 Physical Quantities

Q4. (a) Define physical quantities. Give example and explanation.

(b) Into how many types physical quantities are divided. Define and explain them.

Ans: (a) Physical quantities: All measurable quantities are called physical quantities.

Two common characteristics of physical quantity:

A physical quantity possesses at least two characteristics in common.

(i) Numerical magnitude.

(ii) The unit in which quantity is measured.

Examples:

Length, mass, time and temperature are some examples of physical quantities.

Explanation:

⇒ If the length of a student is 104cm then 104 is its numerical magnitude and centimeter is the unit of measurement.

⇒ When a grocer says that each bag contains 5kg sugar, he is describing its numerical magnitude as well as the unit of measurement.

(b) Divisions of physical quantities:

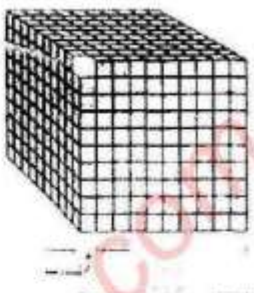
Physical quantities are divided into two divisions.

1. Base quantities. 2. Derived quantities.

(1) Base quantities:

Base quantities are the quantities on the basis of which other quantities are expressed.

There are seven physical quantities which form the foundation for other physical quantities. These physical quantities are called the base quantities.

Example:

Base quantities are length, mass, time, electric current, temperature, intensity of light, and the amount of substance.

Derived quantities:

Those physical quantities which are expressed in terms of base quantities are called the derived quantities.

Examples: Area, volume, speed, force, work, energy, power, electric charge, electric potential etc.

1.3 International System of Units

Q5. (a) What is unit? Why there is a need of unit?

(b) Explain the international system of units and its importance.

Ans: (a) Unit: A standard quantity which is used to measure any physical quantity is called unit.

Need of Unit: Measuring is not simple counting. For example, if we need milk or sugar, we must also understand how much quantity of milk or sugar we are talking about. Thus, there is a need of some standard quantities for measuring or comparing unknown quantity.

(b) International system of units.

The eleventh General Conference on Weight and Measures held in paris in 1960 adopted a world-wide system of measurements called **International System of Units.**

The International System of Units is commonly referred as SI.

Figure 1.2. Measuring height

With the developments in the field of science and technology, the need for a commonly acceptable system of units was seriously felt all over the world particularly to exchange scientific and technical information.

The units that describe base quantities are called base units.

Each base quantity has its SI units.

Given table shows seven base quantities, their SI units and their symbols.

		Name	Symbol
Length	l	metre	m
Mass	m	kilogramme	kg
Time	t	second	s
Electric current	I	ampere	A
Intensity of light	L	candela	cd
Temperature	T	kelvin	K
Amount of substance	n	mole	mol

The units used to measure derived quantities are called derived units.

Derived units are defined in terms of base units and are obtained by multiplying or dividing one or more base units with each other.

The unit of area is (metre)^2 and the unit of volume is (metre)^3. Both are based on the unit of length, which is metre.

So unit of length is the base unit while the unit of area and volume are the derived units.

Speed is defined as distance covered in unit time. Therefore its unit is metre per second.

		Name	Symbol
Speed	v	metre per second	ms^{-1}
Acceleration	a	metre per second per second	ms^{-2}
Volume	V	cubic metre	m^3
Force	F	newton	N or ($kg\ m\ s^{-2}$)
Pressure	P	pascal	Pa or ($N\ m^{-2}$)
Density	ρ	kilogramme per cubic metre	$kg\ m^{-3}$
Charge	Q	coulomb	C or (As)

Quick Quiz

1. How can you differentiate between base and derived quantities?

Ans:

Base quantities	Derived quantities
1. Base quantities are the quantities on the basis of which other quantities are expressed.	1. The quantities that are expressed in terms of base quantities are called derived quantities.
2. Length, temperature, intensity of light etc.	2. Area, volume, speed, force, work, energy, power etc.

2. Identify the following as base or derived quantities: [illegible] length, temperature and volume.

Ans:

Base quantities	Derived quantities
Mass, time, length, temperature.	Density, force, speed, volume.

3. Identify the base quantities in the following.

(i) Speed (ii) Area (iii) Force (iv) Distance

Ans:
- Distance can be considered as base quantity, Because distance is equal to length and its unit is metre.
- Speed, area and force are derived quantities

1.4 PREFIXES

Q7. What are prefixes? Explain your answer with suitable examples.

Ans: Prefixes:

Prefixes are the words or letters added before a unit and stand for the multiples or sub-multiples of that unit. For example, kilo, mega, milli, micro, etc.

Need of Prefixes:

Some of the quantities are either very large or very small.

For example, 250,000m, 0.002 W and 0.00000 2 g,etc.

SI units have the advantage that their multiples and sub-multiples can be expressed in terms of prefixes.

These are useful to express very large or small value.

Table of Prefixes:

Prefixes and their symbol and multiplier are given in the table.

Prefix	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
exa	E	10^{18}	deci	d	10^{-1}
peta	P	10^{15}	centi	c	10^{-2}
tera	T	10^{12}	milli	m	10^{-3}
giga	G	10^{9}	micro	μ	10^{-6}

mega	M	10^6	nano	n	10^{-9}
kilo	k	10^3	pico	p	10^{-12}
hecto	h	10^2	femto	f	10^{-15}
deca	da	10^1	atto	a	10^{-18}

1 km	10^3m
1 cm	10^{-2}m
1 mm	10^{-3}m
1 µm	10^{-6}m
1 nm	10^{-9}m

For the conversion of 20, 000g into kilogramme divide 20, 000g by 1000, since kilo represents 10^3 or 1000.

Thus, $20{,}000\text{g} = \frac{20{,}000}{1000}\text{ kg} = 20\text{kg}$

or $20{,}000\text{g} = 20 \times 10^3\text{ g} = 20\text{ kg}$

$\Rightarrow$ $200{,}000\text{ ms}^{-1}$

$= 200 \times 10^3\text{ ms}^{-1}$ $\quad\because 10^3\text{m} = 1\text{km}$

$200{,}000\text{ms}^{-1} = 200\text{ kms}^{-1}$

4800000 W

$= 4800 \times 1000$ W $\quad\because 10^3\text{ w} = 1\text{kW}$

$= 4800 \times 10^3$ W

4800000 W = 4800 kW

4800000 W

$= 48 \times 10^5$ W

$= 4.8 \times 10^6$ W $\quad\because 10^6\text{ w} = 1\text{MW}$

4800000 W = 4.8 MW

3300, 000, 000 Hz

$= 3300 \times 1000000$

$= 3300 \times 10^6$ Hz

$3300000000\ Hz = 3300\ MHz$ $\quad \because 10^6\ Hz = 1\ MHz$

Or: $3300,000,000\ Hz$
$= 3300 \times 1000000$
$= 3300 \times 10^6$
$= 3.3 \times 10^3 \times 10^6$
$= 3.3 \times 10^9\ Hz$ $\quad \because 10^9\ Hz = 1\ GHz$

$3300000000\ Hz = 3.3\ GHz$

Example: Conversion of gram into micro gram.

$0.00002\ g$
$= 0.02 \times 10^{-3}\ g$ $\quad \because 10^{-6}\ g = 1\ \mu g$
$= 20 \times 10^{-6}\ g$

$0.00002 g = 20\ \mu g$

Example: Conversion of metre into nano metre.

$= 0.000\ 000\ 00\ 81\ m$
$= 0.0081 \times 10^{-6}\ m$
$= 8.1 \times 10^{-6} \times 10^{-3}\ m$ $\quad \because 10^{-9}\ m = 1\ nm$
$= 8.1 \times 10^{-9}\ m$

$0.0000000081 m = 8.1\ nm$

Important points to remember about prefixes:

- Double prefixes are not used in calculations.
  For example, no prefix is used with kilogramme since it already contains the prefix kilo.
- Prefixes are used with both types base and derived units.

1.5 Scientific Notation

Q8. What is scientific notation? Explain your answer by giving examples.

Ans: Scientific notation: A way to express a given number as a number between 1 and 10 multiplied by 10 having an appropriate power, is called scientific notation.

Explanation: A simple but scientific way to write large or small numbers is to express them in some power of ten. The moon is 384000000 metres away from the Earth.

Distance of the Moon from the Earth can also be expressed as 3.84×10^8m.

This form of expressing a number is called the standard form or scientific notation.

Advantage of scientific notation:

Scientific notation saves writing down or interpreting large numbers of zeros.

Example 1 ***A number 62750 can be expressed into its scientific form as.***

62750
$= 6.275 \times 10^4$

0.00045 (s)
= 4.5×10^{-4} s.

kilo (k) = 10^3 centi (c) 10^{-2} milli (m) = 10^{-3}
micro (μ) = 10^{-6} mega (M) = 10^6

as an ordinary whole number. *In scientific notation.*

The distance of Sun from the Earth = 150 million km
= 150×10^6 km

= 150×10^6 km
= $150 \times 10^6 \times 10^3$ m ∵ 1 km = 10^3 m
= 150×10^9 m
= 150000000000 m

= $150 \times 10^6 \times 10^3$
= 150×10^9
= $15 \times 10 \times 10^9$
= 150000000000 m
= 15×10^{10}
= $1.5 \times 10 \times 10^{10}$
= 1.5×10^{11}

= 1.5×10^{11} m ∵ 1 million = 10^6
= $1.5 \times 10^2 \times 10^6 \times 10^3$ 1 km = 10^3 m
= 150 million km

3000000000 ms⁻¹ *6400000 m*
0.0000000016 g *0.0000548 s*

Ans = 3×1000000000 ms^{-1}
= 3×10^9 ms^{-1}

= 64×10^5 m
= $6.4 \times 10 \times 10^5$ m
= 6.4×10^6 m

= $\frac{0.0000000016}{1000.0000000}$ g
= 16×10^{-10} g
= $1.6 \times 10 \times 10^{-10}$ g
= 1.6×10^{-9} g

= $\frac{0.0000548}{10000000}$
= 548×10^{-7}
= $5.48 \times 10^2 \times 10^{-7}$
= 5.48×10^{-5} s

1.6 Measuring Instruments

Q9. For what purpose measuring instruments are used? What are the differences between old and modern instruments?

Ans: Measuring instruments are used to measure various physical quantities such as length, mass, time, volume etc.

Old measuring instruments: Measuring instruments used in the past were not so reliable and accurate as we use today.

Examples: Sundial, water clock and other time measuring devices used around 1300 AD were quite crude.

Modern measuring instruments:

Modern measuring instruments are highly reliable and accurate.

Examples: Digital clocks, watches, calculators, electric balance etc.

FOR YOUR INFORMATION

Hubble space telescope ... the Earth. It provides information about stars.

Q10. Write short notes on following measuring instruments.

1. The metre rule. 2. The measuring tape.

Ans: The metre rule: A metre rule is a length measuring instrument. In the figure given below a simple metre rule is shown.

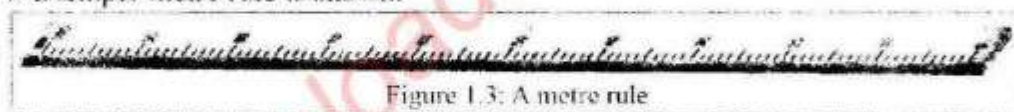



Figure 1.3: A metre rule

Use of metre rule:

Metre rule is commonly used in the laboratories to measure length of an object or distance between two points.

Construction of metre rule:

A metre rule is one metre long which is equal to 100 centimetres. Each centimeter (cm) is divided into 10 small divisions called millimeter (mm)

Least count of metre rule: One millimeter is the smallest reading that can be taken using a metre rule and is called its least count.

Precautionary measures: While measuring length, or distance, eye must be kept vertically above the reading point as shown in the below figure (b).

The reading becomes doubtful if the eye is positioned either left or right to the reading point as shown in the figure (a).

Figure (a) Wrong position of the eye to note the reading. (b) correct position of the eye to note the reading from a metre rule.

(2) Measuring tape: Measuring tape is an instrument which is used to measure length in metres and centimeters.

The given figure shows a measuring tape used by blacksmith and carpenters.

A measuring tape consists of thin and long strip of cotton, metal or plastic generally 10m, 20m, 50m or 100m long.

Measuring tapes are marked in centimeters as well as in inches.

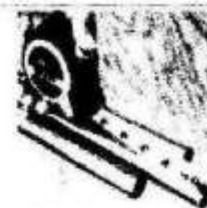



Figure 1.5 A measuring tape

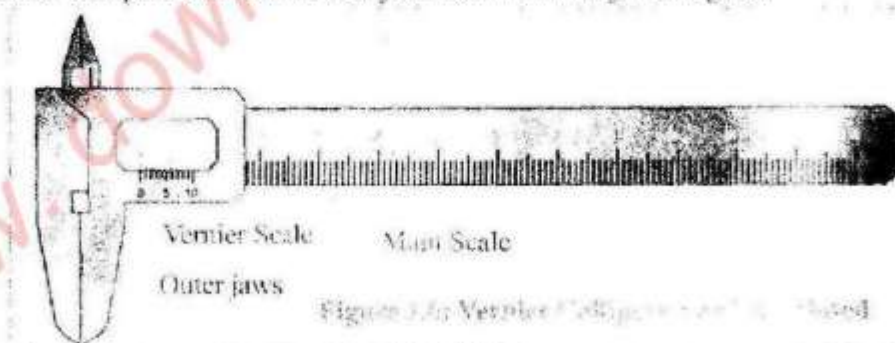
Cut a strip of paper sheet. Fold it along its length. Now mark centimeters and half centimeter along its length using a ruler. Answer the following questions.

What is the range of your paper scale?
What is its least count?
Measure the length of a pencil using your paper scale and with a metre ruler. Which one is more accurate and why?

The range of my paper scale is 20cm.
The least count of my paper scale is half centimeter.
The measurement of pencil measured by the metre ruler is 4.2cm.
The measurement of pencil measured by the ruler is more accurate because it even can measure the length in millimeters.

Vernier callipers is an instrument which is used to measure small lengths such as internal or external diameter or length of a cylinder.

Accuracy greater than 1mm can be obtained by using vernier callipers.

Vernier callipers consists of two jaws as shown in given figure.

One is a fixed jaw with main scale attached to it. Main scale has centimeter and millimeter marks on it.

The other jaw is a moveable jaw. It has vernier scale having 10 divisions over it such that each of its division is 0.9 mm.

Least count of vernier callipers:

The difference between one small division on main scale division and one vernier scale division is 0.1 mm. It is called least count (L.C) of the vernier callipers.

Formula of least count:

Least count of the vernier callipers can also be found by given relation.

$$\text{Least count of vernier callipers} = \frac{\text{Smallest reading on main scale}}{\text{Number of divisions on vernier scale}}$$

$$\text{L.C of vernier callipers} = \frac{1\text{mm}}{10\,\text{divisions}} = 0.1\text{ mm}$$

Hence L.C. = 0.1 mm = 0.01 cm.

So least count of vernier callipers is 0.01cm.

Working of a vernier callipers: First of all find the error in the measuring instrument. It is called the zero error of the instrument.

Zero correction: Knowing the zero error, necessary correction can be made to find the correct measurement. Such a correction is called zero correction of the instrument.

Zero correction is the negative of zero error.

Zero error and zero correction of vernier callipers:

To find the zero error, gently close the jaws of vernier callipers.

Absence of zero error:

If the zero line of the vernier-scale coincides with the zero of the main scale then the **zero** error is **zero** as shown in the given figure (a).

Presence of zero error:

Zero error will exist if zero line of the vernier scale is not coinciding with the zero of main scale.

Zero error are of two types.

(1) Positive zero error. (2) Negative zero error.

Positive zero error: Zero error will be positive if zero line of vernier scale is on the right side of the zero of the main scale. As shown in the figure (b).

Negative zero error:

Zero error will be negative if zero line of vernier scale is on the left side of zero of the main scale. As shown in given figure (c).

Method to take reading on vernier callipers:

Let us find the diameter of a solid cylinder using vernier callipers.

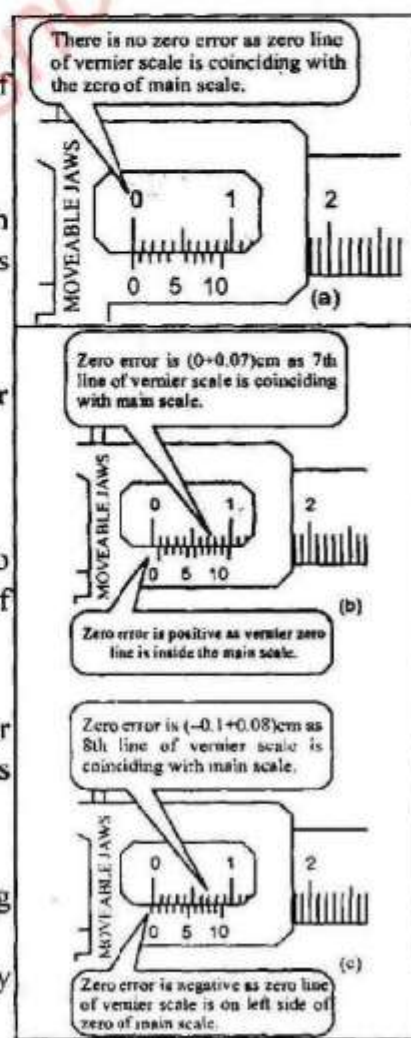
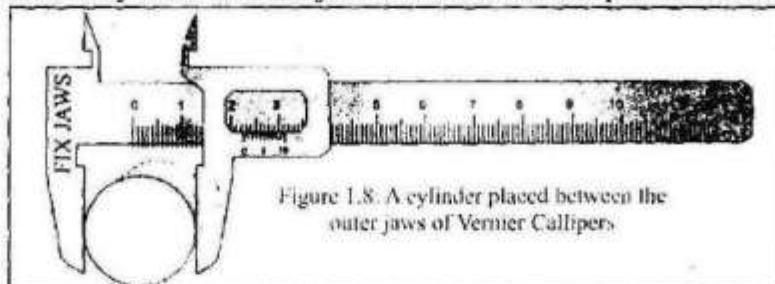
A reading can be taken by vernier callipers by using following steps.

1. Place the solid cylinder between jaws of the vernier callipers as shown in figure.

Figure 1.8: A cylinder placed between the outer jaws of Vernier Callipers

2. Close the jaws till they gently press the opposite sides of the object.
3. Note the complete divisions of main scale past the vernier zero in a tabular form.
4. Find the vernier scale division that is coinciding with any division on the main scale.
5. Multiply this value by least count of vernier callipers and add it in the main scale reading. This is equal to the diameter of the solid cylinder.
6. Add zero correction (Z.C) to get correct measurement.

Repeat the above procedure and record at least three observations with the solid cylinder displaced or rotated each time.

Digital Vernier Callipers

Digital Vernier Callipers has greater precision than mechanical Vernier Callipers. Least count of digital Vernier Callipers is 0.01 mm.

Quick Quiz

1. *What is the least count of the vernier callipers?*

Ans: The least count of the vernier callipers is 0.1 mm or 0.01 cm.

2. *What is the range of the vernier callipers used in your physics laboratory?*

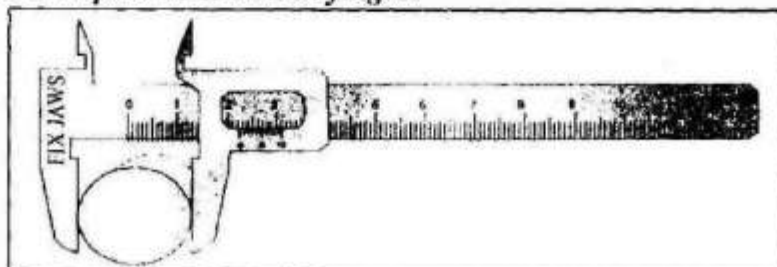
Ans: Range of the vernier callipers used in our physics laboratory is 12cm.

3. *How many divisions are there on its vernier scale?*

Ans: Vernier scale has 10 divisions over it such that each of its division is 0.9 mm.

4. *Why do we use zero correction?*

Ans: Zero correction is used to get correct and exact measurement.

Example 1.1 *Find the diameter of a cylinder placed between the outer jaws of Vernier Callipers as shown in fiugre.*

Solution: Zero correction:

On closing the jaws of Vernier Callipers, the position of vernier scale is on the right side of the zero of the main scale.

Main scale reading	=	0.0cm
Vernier division coinciding with main scale	=	7 div.
Vernier scale reading	=	7 × 0.01 cm
	=	0.07 cm
Zero error	=	0.0cm + 0.07 cm
	=	+ 0.07 cm
Zero correction (Z.C)	=	– 0.07 cm

Diameter of the cylinder:

Main scale reading = 2.2cm

(when the given cylinder is kept between the jaws of the Vernier Callipers as shown in figure of this question).

Vernier div. coinciding with main scale div.	=	6 div.
Vernier scale reading	=	6 × 0.01 cm
	=	0.06cm
Observed diameter of the cylinder	=	2.2cm + 0.06cm
	=	2.26 cm
Correct diameter of the cylinder	=	2.26 cm – 0.07cm
	=	2.19cm

Thus, the correct diameter of the given cylinder as found by Vernier Callipers is 2.19 cm.

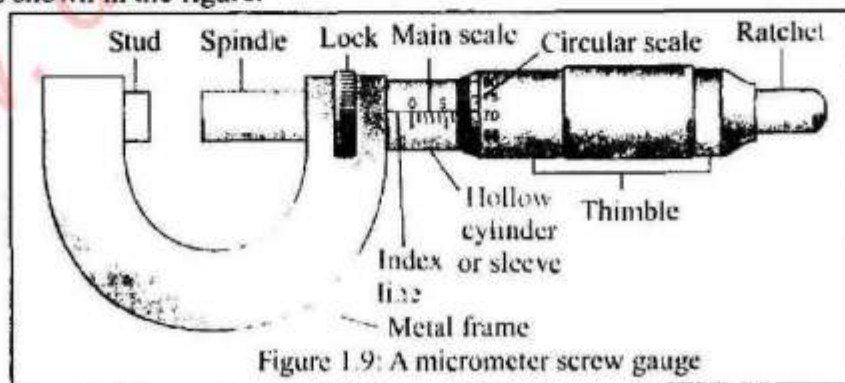
Q12. What is screw gauge? For what purpose it is used? Write a detail note.

Ans: Screw gauge:

A screw gauge is an instrument that is used to measure small lengths with accuracy greater than a vernier callipers. It is also called as micrometer screw gauge.

Construction of screw gauge:

A simple screw gauge consists of a U-shaped metal frame with a metal stud at its one end as shown in the figure.

Figure 1.9: A micrometer screw gauge

Nut:

A hollow cylinder (or sleeve) has a millimeter scale over it along a line called index

line parallel to its axis. The hollow cylinder acts as a nut.

Location of nut:

Nut is fixed at the end of U-shaped frame opposite to the stud.

A thimble has a threaded spindle inside it.

Pitch of the screw: As the thimble completes one rotation, the spindle moves 1mm along the index line. It is because the distance between consecutive threads on the spindle is 1mm. This distance is called the pitch of screw on the spindle, the thimble has 100 divisions around its one end. It is the circular scale of the screw gauge. As thimble completes one rotation, 100 divisions pass the index line and the thimble moves 1mm along the main scale. Thus each division of circular scale crossing the index line moves the thimble through $\frac{1}{100}$ mm or 0.01 mm on the main scale.

Tidbits
Relative sizes of molecules and micro-organisms

Least count of screw gauge: Least count of screw gauge can be found as given below.

$$\text{Least count} = \frac{\text{Pitch}}{\text{Number of divisions on circular scale}}$$

$$\text{Least count} = \frac{1\text{mm}}{100} = 0.01\text{mm}$$

$$\text{Least count} = 0.01\text{mm} = 0.001\text{cm}.$$

Least count of the screw gauge is 0.01 mm or 0.001 cm.

USEFUL INFORMATION:
Least count of ruler is 1 mm. It is 0.1 mm for vernier callipers and 0.01mm for micrometer screw gauge. Thus measurements taken by micrometer screw gauge are the most precise than the other two.

Working of a screw gauge: The first step is to find the zero error of the screw gauge.

Zero error: To find the zero error, close the gap between the spindle and the stud of the screw gauge by rotating the ratchet in the clockwise direction.

Absence of zero error: If zero of circular scale coincides with the index line, then the zero error will be zero as shown in the given figure (a).

Presence of zero error: If zero of circular scale not coincides with the index line, then the zero error will be present in the instrument.

Types of zero error:

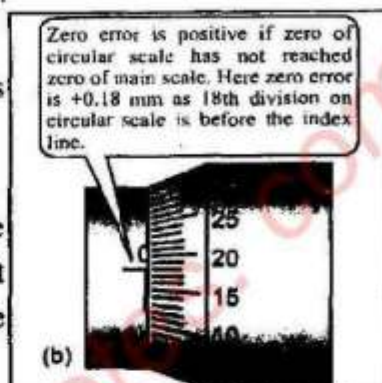
There are two types of zero error.

(1) Positive zero error. (2) Negative zero error.

(1) Positive zero error:

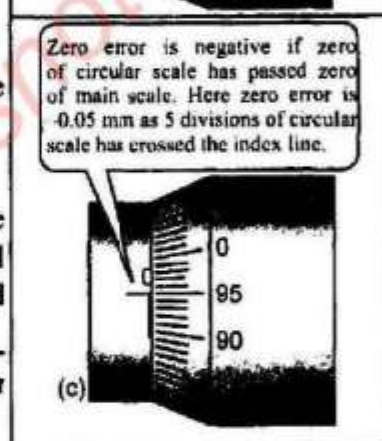
Zero error will be positive if zero of circular scale is behind the index line.

Correction of positive zero error:

In the case of positive zero error, multiply the number of divisions of the circular scale that has not crossed the index line with the least count of screw gauge to find zero error as shown in the figure (b).

(2) Negative zero error:

Zero error will be negative if zero of circular scale has crossed the index line.

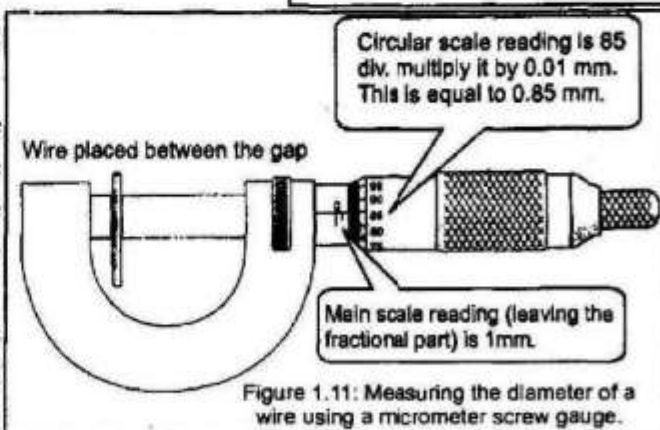
Correction of negative error:

In the case of negative zero error, multiply the number of divisions of the circular scale that has crossed the index line with the least count of screw gauge to find the negative zero error as shown in the given figure (c).

Example 1.2 ***Find the diameter of a wire using a screw gauge.***

Solution: The diameter of given wire can be found as follows:

(i) Close the gap between the spindle and the stud of the screw gauge by turning the ratchet in the clockwise direction.

(ii) Note main scale as well as circular scale readings to find zero error and hence zero correction of the screw gauge.

Figure 1.11: Measuring the diameter of a wire using a micrometer screw gauge.

(iii) Open the gap between stud and spindle of the screw gauge by turning the ratchet in anti-clockwise direction. Place the given wire in the gap as shown in figure 1.11. Turn the ratchet so that the object is pressed gently between the studs and the spindle.

(iv) Note main scale as well as circular scale readings to find the diameter of the given wire.

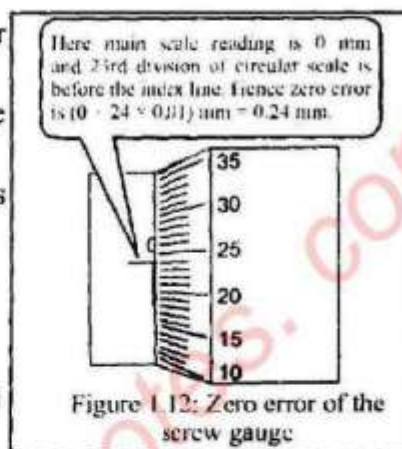
(v) Apply zero correction to get the correct diameter of the wire.

(vi) Repeat steps iii, iv and v at different places of the wire to obtain its average diameter.

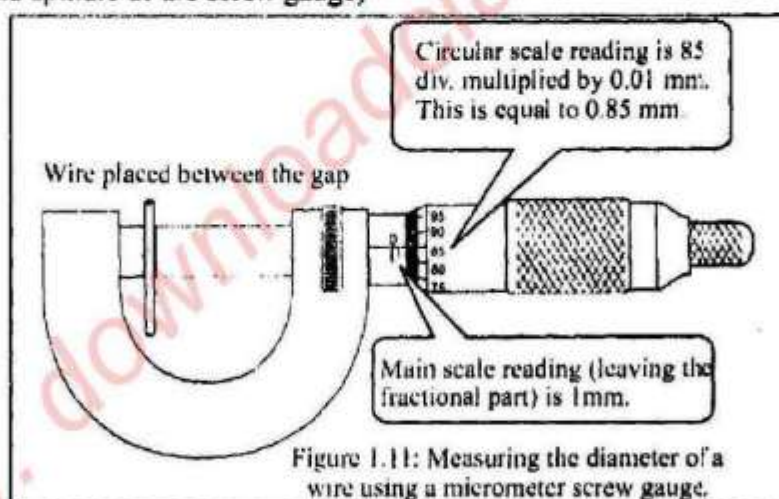
Here main scale reading is 0 mm and 23rd division of circular scale is before the index line. Hence zero error is (0 + 24 × 0.01) mm = 0.24 mm.

Figure 1.12: Zero error of the screw gauge

Zero correction: Closing the gap of the screw gauge as shown in the figure.

Main scale reading	=	0 mm
Circular scale reading	=	24 × 0.01 mm
	=	0.24 mm
Zero error of the screw gauge	=	0 mm + 0.24 mm
	=	+ 0.24 mm
Zero correction Z.C.	=	− 0.24 mm

Diameter of the wire:

Main scale reading = 1mm
(When the given wire is pressed by stud and spindle of the screw gauge)

Figure 1.11: Measuring the diameter of a wire using a micrometer screw gauge.

No. of divisions on circular scale	=	85 div.
Circular scale reading	=	85 × 0.01 mm
	=	0.85 mm
Observed diameter of the given wire	=	1 mm + 0.85 mm
	=	1.85 mm
Correct diameter of the given wire	=	1.85 mm -0.24 mm
	=	1.61 mm

Thus, diameter of the given wire is 1.61 mm.

MINI EXERCISE 3:

1. *What is the least count of a screw gauge?*
2. *What is the pitch of your laboratory screw gauge?*
3. *What is the range of your laboratory screw gauge?*
4. *Which one of the two instruments is more precise and why?*
   (a) Vernier Callipers. (b) Screw Gauge.

Ans: 1. The least count of the screw gauge is 0.01 mm or 0.001 cm.
2. The pitch of our laboratory screw gauge is 1mm.
3. The range of our laboratory screw gauge is 100mm.
4. The instrument, screw gauge is more precise than vernier callipers.

Reason: The least count of vernier callipers is 0.01cm while the least count of screw gauge is 0.001 cm.

Q13. How many instruments are used for the measurement of mass. Write brief information for each.

Ans: Mass - measuring instruments in ancient times:

⇒ Pots were used to measure grain in various part of the world in the ancient times.

⇒ Balances were also used by Greeks and Romans in the ancient times.

Figure 1.13: A beam balance

Mass measuring instruments in recent days:

1. Beam Balance. Now-a- days beam balances are used at many places.

In beam balance the unknown mass is placed in one pan. It is balanced by putting known masses in the other pan.

2. Physical Balance: A physical balance is used in the laboratory to measure the mass of various objects by comparison.

Construction of physical balance: Physical balance consists of a beam resting at the centre on a fulcrum as in the given figure.

Figure 1.14: A physical balance

The beam carries scale pans over the hooks on either side.

Working of physical balance:

Unknown mass if placed on the left pan. Find some suitable standard masses that cause the pointer to remain at zero on raising the beam.

3. Lever Balance: A lever balance consists of a system of levers as shown in the given figure.

Method to measure the object:

When lever is lifted placing the object in one pan and standard masses on the other pan, the pointer of the lever system moves. The pointer is brought to zero by varying standard masses.

Figure 1.15: A lever balance

4. Electronic Balance: Electronic balance is the most precise instrument for the measurement of mass.

A simple electronic balance is shown in figure.

Figure 1.16: An electronic balance

Ranges of electronic balance:

Electronic balances come in various ranges, milligram ranges, gram ranges and kilogramme ranges.

Use of electronic balances: Electronic balances are used in sweet and grocery shops. These are more precise than beam balances and are easy to handle.

Method to measure the mass of object:

⇒ Before measuring the mass of a body, it is **switched on and its reading is set to zero.**

⇒ Place the object to be weighed, on the electronic balance.

⇒ The reading on the balance gives you the mass of the body placed over it.

Example 1.3 ***Find the mass of a small stone by a physical balance.***

Solution: Follow the steps to measure the mass of a given object.

(i) Adjusting the leveling screws with the help of **plumbline** to level the platform of physical balance.

(ii) Raise the beam gently by turning the arresting knob clockwise. Using balancing screws at the ends of its beam, bring the pointer at zero position.

(iii) Turn the arresting knob to bring the beam back on its supports. Place the given object (stone) on its left pan.

(iv) Place suitable standard masses from the weight box on the right pan. Raise the beam. Lower the beam if its pointer is not at zero.

(v) Repeat adding or removing suitable standard masses in the right pan till the pointer rests at zero on raising the beam.

(vi) Note the standard masses on the right pan. Their sum is the mass of the object on the left pan.

Q14. Which balance measures the most accurate mass from the given balances? Explain.

(a) Beam Balance (b) Physical balance (c) Electronic balance

Ans: Which balance measures the most accurate mass, to check this, the mass of one rupee coin is done using different balances as given below:

(a) Beam Balance:

(b) Let the balance measures coin's mass = 3.2g

A sensitive beam balance may be able to detect a change as small as of 0.1 g or 100mg.

(b) Physical balance:

Let the balance measures coin's mass =3.24g

Least count of physical balance.

Least count of the physical balance may be as small as 0.01 g or 10 mg. Thereforce, it measures more accurate than a sensitive beam balance.

USEFUL INFORMATION:

The precision of a balance in measuring mass of an object is different for different balances. A sensitive balance cannot measure largo masses. Similarly a balance that measures large masses cannot be sensitive.

Some digital balances measure even smaller difference of the order of 0.0001g or 0.1 mg. Such balances are considered the most precise balance.

(c) Electronic balance:

Let the balance measures coin's mass=3.247g

Least count of electronic balance.

Least count of electronic balance is 0.001 g or 1mg.

More accurate measurement than beam and physical balance:

The measurement of electronic balance is the more accurate balance than beam and physical balance The electronic balance is the most sensitive balance in the all balances.

MINI EXERCISE 4:

1. *What is the function of balancing screws in a physical balance?*
2. *On what pan we place the object?*

Ans: 1. Balancing screws in a physical balance is used to bring the pointer at zero position

2. Place the object into left pan.

Q15. What is a stopwatch? For what purpose it is used? Also write its working.

Ans: Stop watch:

A stopwatch is an instrument which is used to measure the time interval of an event.

Types of stopwatches: There are two types of stopwatches.

1. Mechanical stopwatches.
2. Digital stopwatches.

(1) Mechanical stopwatches:

A mechanical stopwatch can measure a time interval up to minimum 0.1 second.

A simple mechanical stop watch is shown in the given figure.

Figure 1.17: A mechanical stopwatch

Digital Stopwatch: Digital stopwatch is commonly used in laboratories can measure a time interval as small as 1/100 second or 0.01 second. A simple digital stop watch is shown in figure.

Working of mechanical stopwatch:

A mechanical stopwatch has a knob that is used to wind the spring that powers the watch.

It can also be used as a start-stop and rest button.

Method to start or stop a stopwatch:

Figure 1.18: A digital stopwatch

The stopwatch starts when the knob is pressed once. When pressed second time, it stops the watch while the third press brings the needle back to zero position.

Working of digital stopwatch: The digital stop watch starts to indicate the time lapsed as the start/stop button is pressed. As soon as start/stop button is pressed again, it stops and indicates the time interval recorded by it between start and stop of an event. A reset button restores its initial zero setting.

Q16. What is a measuring cylinder? For what purpose it is needed? How a measuring cylinder can be used?

Ans: A measuring cylinder is a glass or transparent plastic cylinder.

Scale on measuring cylinder: Measuring cylinder has a scale along its length that indicates the volume in millilitre (mL) as shown in figure:

Capacity of measuring cylinder:

Measuring cylinders have different capacities from 100 mL to 2500 mL.

Uses of measuring cylinder:

1. Measuring cylinder is used to measure the volume of a liquid or powdered substance.
2. Measuring cylinder is also used to find the volume of an irregular shaped solid insoluble in a liquid by displacement method.

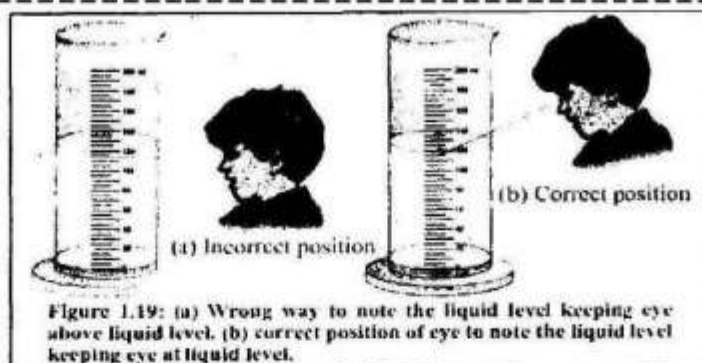
Measuring of volume of solid:

- The solid is lowered into a measuring cylinder containing water / liquid.
- The level of water / liquid rises.
- The increase in the volume of water / liquid is the volume of the given solid object.

Method to use a measuring cylinder:

While using a measuring cylinder, it must be kept vertical on a plane surface.

1. Take a measuring cylinder.
2. Place it vertically on the table.
3. Pour some water into it.
4. Note the surface of water is curved as shown in the given figure.

Figure 1.19: (a) Wrong way to note the liquid level keeping eye above liquid level. (b) correct position of eye to note the liquid level keeping eye at liquid level.

Meniscus of the liquids: The meniscus of the most liquids curve downwards while the meniscus of mercury curves upwards.

Correct method to note the liquid level:

The correct method to note the level of a liquid in the cylinder is to keep the eye at the same level as the meniscus of the liquid as shown in above figure (b)

Incorrect method to note the liquid level:

The incorrect method to note the liquid level keeping the eye above the level of liquid as shown in above figure (a).

Level of eye:

When the eye is above the liquid level, the meniscus appears higher on the scale. Similarly, when the eye is below the liquid level, the meniscus appears lower than actual height of the liquid.

Measuring volume of an irregular shaped solid: Measuring cylinder can be used to find the volume of a small irregular shaped solid that sinks in water.

Volume of a small stone can be found out as following:

1. Take some water in a graduated measuring cylinder.
2. Note the volume V_i of water in the cylinder.
3. Tie the solid with a thread.
4. Lower the solid into the cylinder till it is fully immersed in water.
5. Note the volume V_f of water and the solid.
6. Volume of the solid will be $V_f - V_i$.

Q17. Which equipments are essential for the laboratory safety. Also write rules of laboratory safety.

Ans: LABORATORY SAFETY EQUIPMENTS:

A school laboratory must have safety equipments such as:

- ☆ Waste-disposal basket
- ☆ Fire extinguisher
- ☆ Fire alarm.
- ☆ First Aid Box.
- ☆ Sand and water buckets.
- ☆ Fire blanket to put off fire.

☆ Substances and equipments that need extra care must bear proper warning signs such as given below:

Radioactive Poison General danger Flammable Explosive Electric hazard

LABORATORY SAFETY EQUIPMENTS:

Fire extinguisher

LABORATORY SAFETY RULES: The students should know what to do in case of an accident. The charts or posters are to be displayed in the laboratory to handle situations arising from any mishap or accident. For your own safety and for the safety of others in the laboratory, follow safety rules given below:

- Do not carry out any experiment without the permission of your teacher.
- Do not eat, drink, play or run in the laboratory.
- Read the instructions carefully to familiarize yourself with the possible hazards before handling equipments and materials.
- Handle equipments and materials with care.
- Do not hesitate to consult your teacher in case of any doubt.
- Do not temper with the electrical appliances and other fittings in the laboratory.
- Report any accident or injuries immediately to your teacher.

Q18. What are significant figures? Which rules are helpful in identifying significant figure?

Ans: Significant Figures: All the accurately known digits and the first doubtful digit in an expression are called significant figures. It reflects the precision of a measured value of a physical quantity.

Rules to identify the significant figures.

The following rules are helpful identifying significant figure.

(1) Non-zero digits are always significant.

(2) Zeros between two significant figures are also significant.

(3) Final or ending zeros on the right in decimal fraction are significant.

(4) Zeros written on left side of the decimal point for the purpose of spacing the decimal point are not significant.

RULES TO FIND THE SIGNIFICANT DIGITS IN A MEASUREMENT

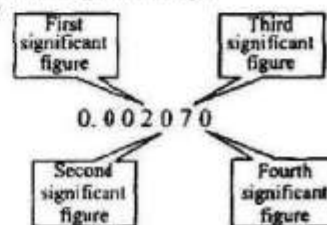
(i) **digits other than zero are always significant.**
27 has 2 significant digits.
275 has 3 significant digits.

(ii) **Zero between significant digits are also significant.**
2705 has 4 significant digits.

(iii) **Final zero or zeros after decimal are significant.**
275.00 has 5 significant digits.

(iv) **Zeros used for spacing the decimal point are not significant. Here zeros are placeholders only.**
0.03 has 1 significant digit.
0.027 has 2 significant digits

Example:

First significant figure, Third significant figure
0.002070
Second significant figure, Fourth significant figure

(5) In whole numbers that end in one or more zeros without a decimal point. These zeros may or may not be significant.

⇒ In such cases, it is not clear which zeros serve to locate the position value and which are actually parts of the measurements.

⇒ In such a case, express the quantity using scientific notation, to find the significant zero.

Example 1.4 ***Find the number of significant figures in each of the following values. Also express them in scientific notations.***

(a) 100.8 s (b) 0.00580 km (c) 210.0g

Solution:

(a) All the four digits are significant. The zeros between the two significant figures 1 and 8 are significant. To write the quantity in scientific notation, we move the decimal point two places to the left, thus.

$100.8\ s = 1.008 \times 10^{-2}\ s$

(b) The fist two zeros are not significant. They are used to space the decimal point. The digit 5,8 and the final zero are significant. Thus there are three significant figures. In scientific notation, it can be written as 5.80×10^{-3} km.

Rounding Numbers:

(i) **If the last digit is less than 5 then it is simply dropped. This decreases the number of significant digits in the figure.**

For example: 1.943 is rounded to 1.94 (3 significant figure)

(ii) **If the last digit is greater than 5, then the digit on its left is increased by one. This also decreases the number of significant digits in the figure.**

For example: 1.47 is rounded to two significant digits 1.5

(iii) **If the last digit is 5, then it is rounded to get nearest even number.**

For example: 1.35 is rounded to 1.4 and 1.45 is also rounded to 1.4

(c) The final zero is significant since it comes after the decimal point. The zero between last zero and 1 is also significant because it comes between the significant figures. Thus the number of significant figures in this case is four. It can be written as $210.0g = 2.100 \times 10^{2}g$.

Q19. How value of physical quantity can be expressed? On which factors, accuracy in measuring a physical quantity depends. Explain with examples.

Ans: The value of a physical quantity is expressed by a number followed by some suitable unit. Every measurement of a quantity is an attempt to find its true value.

Factors in which accuracy depends:

The accuracy in measuring a physical quantity depends upon various factors.

- ☆ The quantity of the measuring instrument.
- ☆ The skill of the observer.
- ☆ The number of the observation made.

Explanation: For example, a student measures the length of a book as 18cm using a measuring tape. The numbers of significant figures in his/her measured values are two. The left digit 1 is the accurately known digit. While the digit 8 is the doubtful digit for

which the student may not be sure.

Another student measures the same book using a ruler and claims its length to be 18.4 cm. In this case all the three figures are significant. The two left digits 1 and 8 are accurately known digits. Next digit 4 is the doubtful digit for which the student may not be sure.

A third student records the length of the book as 18.425 cm. Interestingly, the measurement is made using the same ruler. The numbers of significant figures is again three; consisting of two accurately known digits 1.8 and the first doubtful digit 4. The digits 2 and 5 are not significant. It is because the reading of these last digits cannot be justified using a ruler. Measurement upto third or even second decimal place is beyond the limit of the measuring instrument.

An improvement in the quality of measurement by using better instrument increases the significant figures in the measured result.

SUMMARY

- Physics is a branch of Science that deals with matter, energy and their relationship.
- Some main branches of physics are mechanics, heat, sound, light (optics), electricity and magnetism, nuclear physics and quantum physics.
- Physics plays an important role in our daily life. For example, electricity is widely used every where, domestic appliances, office equipments, machines used in industry, means of transport and communication etc work on the basic laws and principles of physics.
- A measurable quantity is called a physical quantity.
- **Base Quantities:** These are defined independently. Seven quantities are selected as base quantities. These are length, time, mass, electric current, temperature, intensity of light and the amount of a substance.
- **Derived quantities:** The quantities which are expressed in terms of base quantities are called derived quantities. For example speed, area, density, force, pressure, energy etc.
- **International System of Units:** A world-wide system of measurements is known as international system of units (SI). In SI, the units of seven base quantities are metre, kilogramme, second, ampere, kelvin, candela and mole.
- **Prefixes:** These are the words or letters added before a unit and stand for the multiples or submultiples of that unit. For example, kilo, mega, milli, micro, etc.
- **Scientific notation:** It is a way to express a given number as a number between 1 and 10 multiplied by 10 having an appropriate power. It is also called its standard form.
- **Vernier Callipers:** An instrument used to measure small lengths such as internal or external diameter or length of a cylinder etc.

- **Screw gauge:** It is used to measure small lengths such as diameter of a wire, thickness of a metal sheet etc.
- **Physical balance:** It is a modified type of beam balance used to measure small masses by comparison with greater accuracy.
- **Stopwatch:** It is used to measure the time interval of an event. Mechanical stop watches have least count upto 0.1 second. Digital stop watch of least count 0.01 seconds are common.
- **Measuring Cylinder:** It is a graduated glass cylinder marked in millilitres. It is used to measure the volume of a liquid and also to find the volume of an irregular shaped solid object.
- **Significant figures:** All the accurately known digits and the first doubtful digit in an expression are called significant figures. It reflects the precision of a measured value of a physical quantity.

SOLVED QUESTIONS

1.1 Encircle the correct answer from the given choices.

(i) The number of base units in SI are:
(a) 3 (b) 6 (c) 7 (d) 9

(ii) Which one of the following unit is not a derived unit?
(a) pascal (b) kilogramme (c) newton (d) watt

(iii) Amount of a substance in terms of numbers is measured in:
(a) gram (b) kilogramme (c) newton (d) mole

(iv) An interval of 200 μs is equivalent to:
(a) 0.2 s (b) 0.02 s (c) 2×10^{-4} s (d) 2×10^{-6} s

(v) Which one of the following is the smallest quantity?
(a) 0.01 g (b) 2 mg (c) 100 μg (d) 5000 ng

(vi) Which instrument is most suitable to measure the internal diameter of a test tube?
(a) metre rule (b) vernier callipers (c) measuring tap (d) screw gauge

(vii) A student claimed the diameter of a wire as 1.032 cm using vernier callipers. Upto what extent do you agree with it?
(a) 1 cm (b) 1.0 cm (c) 1.03 cm (d) 1.032 cm

(viii) A measuring cylinder is used to measure:
(a) mass (b) area (c) volume (d) level of a liquid

(ix) A student noted the thickness of a glass sheet using a screw gauge. On the main scale, it reads 3 divisions while 8th division on the circular scale coincides with index line. Its thickness is:

(a) 3.8 cm (b) 3.08 mm (c) 3.8 mm (d) 3.08 m

(x) Significant figures in an expression are:

(a) all the digits (b) all the accurately known digits

(c) all the accurately known digits and the first doubtful digit

(d) all the accurately known and all the doubtful digits

Ans: (i) 7 (ii) kilogramme (iii) mole (iv) 2×10^{-4} s (v) 5000 ng

(vi) vernier callipers (vii) 1.03 cm (viii) volume (ix) 3.08 mm

(x) all the accurately known digits and the first doubtful digit

1.2 What is the difference between base quantities and derived quantities? Give three examples in each case.

Ans:

Base Quantities	Derived Quantities
⇒ Base quantities are the quantities on the basis of which other quantities are expressed.	⇒ The quantities that are expressed in terms of base quantities are called derived quantities.
⇒ Length, mass, time, electric current, temperature, intensity of light and amount of substance are examples of base quantities.	⇒ Volume, speed, force, work, energy, power and electric charge are some examples of derived quantities.

1.3 Pick out the base units in the following:

joule, newton, kilogramme, hertz, mole, ampere, metre, kelvin, coulomb and watt

Ans: kilogramme, mole, ampere, metre and kelvin are the base units.

1.4 Find the base quantities involved in each of the following derived quantities.

(a) speed (b) volume (c) force (d) work

(a) Speed:

Ans: The formula of speed is:

$$\text{Speed} = \frac{\text{distance covered by body}}{\text{time taken}}$$

$$\text{Unit of Speed} = \frac{\text{metre}}{\text{second}} = \text{ms}^{-1}$$

⇒ Unit of speed shows that speed is a derived quantity and it is derived from length and time. Metre is the unit of length and second is the unit of time.

⇒ Length and time are base quantities.

(b) Volume:

Ans: The formula of volume is:

Volume = Length × width × height

Unit of volume:

Volume = metre × metre × metre
= m^3

⇒ The unit of volume shows that volume is a derived quantity and is obtained from the length.

⇒ Length is a base quantity and its unit is metre.

(c) Force:

Ans: The formula of force is:

Force = mass × acceleration
F = m × a

Unit of force:

Force = kilogramme × metre per second per second
= kg ms^{-2}

⇒ The unit of mass is kilogramme, the unit of length is metre and the unit of time is second.

⇒ The unit of force shows that it is a derived quantity.

⇒ Force is derived from mass, length and time. Mass, length and time are base quantities

(d) Work:

Ans: The formula of work is:

Work = F × S

Unit of work:

work = $kgms^{-2}$ × m
= $kgm^2 s^{-2}$

⇒ Unit of work shows that it is a derived quantity. Work is derived from the mass, length and time.

⇒ Mass, length and time are base quantities.

1.5 Estimate your age in seconds.

Ans: Supposed age of a person = 15 years.
Total days in one year = 365 days.
Total days in 15 years = 365 × 15 = 5475 days
Total hours in one day = 24 hours.
Total hours in 5475 days = 5475 × 24 = 131,400 hours
Total minutes in one hours = 60 minutes
Total minutes in 131,400 hours = 131,400 × 60 = 7884000 minutes
Total seconds in one minutes = 60 seconds.
Total seconds in 7884000 minutes = 7884000×60
15 years of age = 473,040,000 seconds

By the given method you can convert your exact age into seconds.

1.6 What role SI units have played in the development of science?

Ans: SI units have played a very important role in the development of science.

SI units are very helpful to exchange scientific and technical information at the international level.

1.7 What is meant by vernier constant?

Ans: The least count of the vernier callipers is also called the vernier constant. It can be defined as:

The difference between one small division on main scale division and one vernier scale division is 0.1 mm. It is called least count (LC) of the vernier callipers.

Least count of the vernier callipers can also be found as given below.

$$\text{Least count of vernier callipers} = \frac{\text{Smallest reading on the main scale}}{\text{Number of divisions on vernier scale}}$$

1.8 What do you understand by the zero error of a measuring instrument?

Ans: By closing the jaws of measuring device, if the zero line of one scale (vernier scale) coincides with the zero line of its main scale (other scale) then there is no zero error. But zero error will exist if the zero line of one scale (vernier scale) is not coinciding with the zero of other scale (main scale). Zero error will be positive if zero line of one scale (vernier scale) is on the right side of the zero of other scale (main scale) and will be negative if zero line of one scale (vernier scale) is on the left side of zero of the other scale (main scale).

1.9 Why is the use of zero error necessary in a measuring instrument?

Ans: Zero error is necessary in measuring instrument to obtain an extreme correct value.

1.10 What is a stopwatch? What is the least count of a mechanical stop watch you have used in the laboratories?

Ans: Stopwatch is a device which is used to measure the time interval of an event.

Mechanical stopwatch have least count upto 0.1 second.

1.11 Why do we need to measure extremely small interval of times?

Ans: In nature and also in physics, there are so many phenomenon which vary with respect to the extremely small interval of time and for their experimental measurement we need very precise time measuring instrument. We need to measure extremely small interval of times to calculate the time intervals of natural and artificial events.

1.12 What is meant by significant figures of a measurement?

Ans: All the accurately known digits and the first doubtful digit in an expression are called significant figures.

Significant figure reflects the precision of a measured value of a physical quantity.

1.13 How is precision related to the significant figures in a measured quantity?

Ans: An improvement in the quality of measurement by using better instrument increases the significant figures in the measured results. The significant figures are all the digits are known accurately and the one estimated digit.
More significant figure means greater precision.

SOLVED PROBLEMS

1.1 Express the following quantities using prefixes.

(a) 5000g (b) 2000 000 W (c) 52×10^{-10} kg (d) 225×10^{-8} s

Ans:

(a) 5000 g

Multiplying and dividing by "10^3"

$$= \frac{5000\,g}{10^3} \times 10^3 = \frac{5000\,g}{1000} \times 10^3$$

$$= 5 \times 10^3\ g$$

$$5000g = \boxed{5\ kg}\quad [\because 1kg = 10^3 g]$$

(b) 2000 000 W

Multiplying and dividing by "10^6"

$$= \frac{2000000\,W}{10^6} \times 10^6$$

$$= \frac{2000000}{10^6} \times 10^6\,W = \frac{2000000}{1000000} \times 10^6\,W$$

$$= 2 \times 10^6\ W$$

$$\boxed{2000000\ W = 2MW}\quad [\because 1MW = 10^6 W]$$

(c) 52×10^{-10} kg

$$= 52 \times 10^{-10} \times 10^{+3}\ g$$

$$\because \quad [1\ kg = 10^3\ g]$$

$$= 5.2 \times 10 \times 10^{-10} \times 10^3\ g$$

$$= 5.2 \times 10^4 \times 10^{-10}\ g$$

$$= 5.2 \times 10^{-6}\ g$$

$$[\because 1\mu g = 10^{-6} g]$$

$$= \boxed{5.2\ \mu g}$$

(d) 225×10^{-8} s

$$= 2.25 \times 10^2 \times 10^{-8}\ s$$

$$= 2.25 \times 10^{-6}\ s$$

$$[\because 1\mu s = 10^{-6} s]$$

$$= \boxed{2.25\ \mu s}$$

1.2 How do the prefixes micro, nano and pico relate to each other?

Ans: Relation between micro,nano and pico.

As we know.

micro $= \mu = 10^{-6}$

nano $= n = 10^{-9}$

Pico $= p = 10^{-12}$

The relation between micro, nano and pico can be written as.

micro $= 10^{-6}$

nano $= 10^{-6} \times 10^{-3} = 10^{-3}$ micro

Pico $= 10^{-6} \times 10^{-6} = 10^{-6}$ micro

1.3 Your hair grow at the rate of 1mm per day. Find their growth rate in nms^{-1}.

Ans: Given Data:

growth rate = 1mm/day

growth rate = 1×10^{-3} m/day

Required: growth rate in nms^{-1} = ?

Calculations: First we convert days into seconds

As; 1 day = 24 hours

1 hour = 60 minutes

1 minute = 60 seconds

So;

1 day = 24 × 60 × 60 seconds

1 day = 86400 s

Now we convert "m" in "nm"

As; $\frac{1 \times 10^{-3} m}{10^{-9}} \times 10^{-9}$

$= 1 \times 10^{-3} \times 10^{+9} \times 10^{-9}$ m

$= 10^{+6}$ nm $\quad [\because 10^{-9} m = 1nm]$

Consequently:

$$\text{growth rate} = \frac{10^6 \text{nm}}{86400}$$

growth rate in nms^{-1} = $\boxed{11.57 \text{ nms}^{-1}}$

Alternative method:

Rate of the growth of hair = 1mm per day.

$= 1 \times 10^{-3} \frac{m}{day}$

Rate of growth in nano meter per day $= 1 \times 10^{-3} \times 10^{9} \frac{nm}{day}$

$= 1 \times 10^{6}$ nm/day

Rate of growth in nanometer per hour $= \frac{1 \times 10^6}{24}$ nm/h

$= 4.167 \times 10^{4}$ nm/h

Rate of growth in nanometer per minute $= \frac{4.167 \times 10^4}{60}$ nm/min

$= 6.94 \times 10^{2}$ nm/min

Rate of growth in nanometer per second $= \frac{6.94 \times 10^2}{60}$ nm/sec

Rate of growth $= 1.157\times10^{1}\ \text{nm/sec} = 11.57\ \text{nm/sec}$

Answer: The rate of the growth of hair in nano metre per second is 11.57.

1.4 Rewrite the following in standard form.

(a) 1168×10^{-27} (b) 32×10^{5} (c) 725×10^{-5} kg (d) 0.02×10^{-8}

(a) 1168×10^{-27}

$= 1.168\times10^{3}\times10^{-24}$

$= \boxed{1.168\times10^{-24}}$

(b) 32×10^{5}

$= 3.2\times10\times10^{5}$

$= \boxed{3.2\times10^{6}}$

(c) 725×10^{-5} kg

$= 725\times10^{-5}\times10^{3}\text{g}$

$= 7.25\times10^{2}\times10^{-5}\times10^{3}\ \text{g}$

$= 7.25\times10^{5}\times10^{-5}\ \text{g}$

$= \boxed{7.25\ \text{g}}$

(d) 0.02×10^{-8}

$= \frac{2}{100}\times10^{-8}$

$= \frac{2}{10^{2}}\times10^{-8}$

$= 2.0\times10^{-2}\times10^{-8}$

$= \boxed{2\times10^{-10}}$

1.5 Write the following quantities in standard form.

(a) 6400 km (b) 380 000 km (c) 300,000,000 ms^{-1} (d) second in a day

Ans:

(a) 6400 km

Multiplying and dividing by "10^{3}"

$= \frac{6400\text{m}}{1000}\times10^{3}\ \text{km}$

$= \frac{64}{10}\times10^{3}\text{km}$

$= \boxed{6.4\times10^{3}\text{km}}$ Answer

(b) 380,000 km

Multiplying and dividing by 10^{5}.

$= \frac{380000}{10^{5}}\times10^{5}\text{km}$

$= \frac{380000}{100000}\times10^{5}\text{km}$

$= \boxed{3.8\times10^{5}\ \text{km}}$ Answer

(c) 300000000 ms^{-1}

Multiplying and dividing by "10^{8}"

$$= \frac{300000000\text{ms}^{-1}}{100000000} \times 10^8$$

$$= \boxed{3 \times 10^8 \text{ms}^{-1}} \quad \text{Answer}$$

(d) Seconds in a day

As we know

1 day = 24 hours

1 hour = 60 minutes

1 minute = 60 seconds

So

1 day = 24 × 60 × 60 seconds

1 day = 86400 s

1 day = 86400 s

Multiplying & dividing by 10^4

$$\frac{86400}{10000} \times 10^4 \text{ s}$$

$$= \boxed{8.64 \times 10^4 \text{ s}}$$

Alternative Method:

Hours in a day = 24

Minutes in a day = 24×60 = 1440 minutes

Seconds in a day = 1440×60 = 86400 seconds

Standard form of 86400 seconds:

86400 = 864×100

86400 seconds = 864×10^2

86400 seconds = $8.64 \times 10^2 \times 10^2$

$$\boxed{86400 \text{ seconds} = 8.64 \times 10^4 \text{ Seconds}}$$

1.6 On closing the jaws of a vernier callipers, zero of the vernier scale is on the right to its main scale such that 4th division of its vernier scale coincides with one of the main scale division. Find its zero error and zero correction.

Ans: Data:

Main scale reading = 0.0cm.

Vernier division coinciding with main scale = 4th division

Solution:

Vernier scale reading = 4 × 0.01 cm = 0.04 cm

Zero error = 0.0cm + 0.04cm = 0.04 cm

Zero correction (Z.C) = –0.04cm

Answer: The zero error of the vernier scale is 0.04cm and its zero correction is –0.04cm.

1.7 A screw gauge has 50 divisions on its circular scale. The pitch of the screw gauge is 0.5 mm. What is its least count?

Data: Divisions on the circular scale of screw gauge = 50 division

Pitch of the screw gauge = 0.5mm

Required: Least count of the screw gauge = ?

Formula:

$$\text{Least count} = \frac{\text{Pitch}}{\text{Number of divisions on circular scale}}$$

$$\text{Least count} = \frac{0.5\text{mm}}{50\,\text{divisions}}$$

Least count = 0.01 mm

Least count = 0.01mm = 0.001cm

1.8 Which of the following quantities have three significant figures?

(a) 3.0066 m (b) 0.00309 kg (c) 5.05×10^{-27} kg (d) 301.0 s

(a) 3.0066 m

The significant figures in this quantity are five.

Because the zeros between significant figures are also significant.

(b) 0.00309 kg

The significant figures in this quantity are three.

Because zeros used for spacing the decimal point are not significant.

(c) 5.05×10^{-27} kg

The significant figures in this quantity are three.

Because the zeros between significant figures are also significant.

(d) 301.0 (s)

The significant figures in this quantity are four.

Because the zeros after decimal are significant.

From all the quantities (b) and (c) have three numbers of significant figures.

1.9 What are the significant figures in the following measurements?

(a) 1.009 m (b) 0.00450 kg (c) 1.66×10^{-27} kg (d) 2001 s

(a) 1.009m.

The significant figures in this quantity are four. 1, 0, 0, and 9.

Because the zeros between significant figures are also significant.

(b) 0.00450 kg.

The significant figures in this quantity are three.

Because the zeros used for spacing the decimal point are not significant.

(c) 1.66×10^{-27} kg.

The significant figures in this quantity are three. 1, 6, and 6.

All the digits before the 10^{-27} are significant.

(d) 2001 s.

The significant figures in this quantity are four. 2, 0, 0 and 1.
Because the zeros between the significant figures are also zero.

1.10 A chocolate wrapper is 6.7 cm long and 5.4 cm wide. Calculate its area upto reasonable number of significant figures.

Data: Length of the chocolate wrapper = 6.7cm.
Width of the chocolate wrapper = 5.4cm

Required: Area = ?

Formula: Area = Length × Width

Solution: A = 6.7 cm × 5.4 cm

A = 36 . 18cm

$$\boxed{A = 36\,\text{cm}^2}$$

Answer: The area of the given chocolate wrapper is $36cm^2$.

OBJECTIVE TYPE QUESTIONS (MCQ'S+SHORT ANSWER) FROM PREVIOUS ANNUAL PAPERS OF ALL SECONDARY BOARDS
(LAHORE, GUJRANWALA, FAISALABAD, MULTAN, SAHIWAL, SARGODHA, RAWALPINDI, D.G. KHAN And BAHAWALPUR)

1.1 Introduction To Physics
1.2 Physical Quantities
1.3 International System of Units

☆ **Tick the correct answer.**

1. **The study of internal structure of the earth is:** (GRW. G I & G II)
   (A) Atomic Physics (B) Geo Physics (C) Sound (D) Heat
2. **Which one of the following units is not a derived unit:** (LHR. GI, SGD. GII)
   (A) Pascal (B) Kilogram (C) Newton (D) Watt
3. **One cubic meter is equal to:** (GRW. G I)
   (A) 100 liter (B) 1000 liter (C) 10000 liter (D) $\frac{1}{1000}$ liter
4. **The number of base units in SI are:** (SWL. GI, FBD. GII, SGD. GI, BWP. GII)
   (A) 7 (B) 3 (C) 6 (D) 9
5. **Amount of matter in a substance is measured in SI unit by:** (SGD. GII)
   (A) Gram (B) Kilogram (C) Newton (D) Mole
6. **Amount of a substance in terms of numbers is measured in:** (DGK. GII, FBD. GI)
   (A) Gram (B) Kilogram (C) Newton (D) Mole
7. **Volume of one litre is equal to:** (LHR. GI, RWP. GI)
   (A) $1cm^3$ (B) $10cm^3$ (C) $100cm^3$ (D) $1000cm^3$

Answers

1.	Geo Physics	2.	Kilogram	3.	1000 liter	4.	7
5.	Kilogram	6.	Mole	7.	$1000cm^3$		

☆ **Give short answer to the following questions.**

1. **Define Physics.** (LHR. GI, FBD. GI, MLN. GI SGD. GII)

Ans. Physics is a branch of science, in which matter, energy and their interaction are studied.

2. **Differentiate between Plasma Physics and Geo Physics.** (SGD. GI, GRW. GII)

Ans. Plasma Physics: It is the study of production, properties of the ionic state of matter-the fourth state of matter.

Geo physics: It is the study of the internal structure of the Earth.

3. **Differentiate between atomic physics and plasma physics.** (RWP. GI, BWP. GI)

Ans. Atomic physics: It is the study of the structure and properties.

Plasma physics: It is the study of production, properties of the ionic state of matter the fourth state of matter.

4. **Define electromagnetism.** (GRW. GI)

Ans. It is the study of the charges at rest and in motion, their effects and their relationship with magnetism.

5. **Define atomic physics and nuclear physics.** (FBD. GII, RWP. GII)

Ans. Atomic Physics: It is the study of the structure and properties of atoms.

Nuclear physics: It deals with the properties and behaviour of nuclei and the particles within the nuclei.

6. **Define Mechanics and Geophysics.** (MLN. GII)

Ans. Mechanics: This branch of physics is the study of motion of objects, its causes and effect.

Geophysics: It is the study of the internal structure of the Earth.

7. **Define the term Mechanics and Electromagnetism.** (BWP. GII)

Ans. Mechanics: This branch of physics is the study of motion of objects, its causes and effect.

Electromagnetism: It is the study of the charges at rest and in motion, their effects and their relationship with magnetism.

8. **Write two advantages of Physics in our daily life.** (BWP. GII)

Ans. 1. A car is made on the principles of mechanics.

2. A refrigerator is based on the principles of thermodynamics.

9. **What is the difference between base and derived quantities?**

Ans. Base Quantities (GRW. GI & GII, DGK. GI, FBD. GII, RWP. GII)

☆ Base quantities are the quantities on the basis of which other quantities are expressed.

- ☆ Length, mass, time electric current, temperature, intensity of light and amount of substance are examples of base quantities.

Derived Quantities

- ☆ The quantities that are expressed in terms of base quantities are called derived quantities.
- ☆ Volume, speed, force, work, energy, power and electric charge are some examples of derived quantities.

10. Name any two base quantities. (MLN. GI)

Ans. Length, Mass

11. What is meant by derived quantities? Give two examples. (SWL. GII, SGD. GII, LHR. GI, BWP. GI)

Ans. The units used to measure derived quantities are called derived units.

OR Derived units are defined in terms of base units and are obtained by multiplying or dividing one or more base units with each other.

12. What is meant by International System of Units? (SGD. GI)

Ans. The eleventh General Conference on Weight and Measures held in paris in 1960 adopted a world-wide system of measurements called, International System of Units. The International System of Units is commonly neferred as SI.

13. Define base quantities and base units. (MLN. GII, SWL. GI, FBD. GI, RWP. GI)

Ans. Base quantities: Base quantities are the quantities on the basis of which other quantities are expressed. (OR)

There are seven physical quantities which form the foundation for other physical quantities. These physical quantities are called the base quantities.

Base units: The units that describe base quantities are called base units. Each base quantity has its SI units.

14. Write the names of four derived units. (DGK. GII)

Ans. Speed, acceleration, volume, force

1.4+1.5	Prefixes+Scientific Notation
1.6+1.7	Measuring Instruments+Significant Figures

☆ Tick the correct answer.

1. Which one of the following is the smallest quantity: (LHR. GII, MLN. GII)

(A) 0.01g (B) 2 mg (C) 100μg (D) 5000 ng

2. One micro meter is equal to: (FBD. G II)

(A) 10^{-6}m (B) 10^{-3}m (C) 10^{-9}m (D) 10^{3}m

3. One milliliter is equal to: (MLN. G II)

(A) $1mm^3$ (B) $1cm^3$ (C) $1dm^3$ (D) $1m^3$

4. An interval of 200μs is equivalent to: (SWL. G I, GRW. GI)
(A) 0.2s (B) 0.02s (C) 2×10^{-4}s (D) 2×10^{-6}s

5. One giga gram is equal to: (SWL. G II, 2015)
(A) 10^9 g (B) 10^6 g (C) 10^3 g (D) 10^{-6} g

6. A measuring cylinder is used to measure: (FBD. G I, BWP. G II, MLN. GI)
(A) Mass (B) Area (C) Volume (D) Level of a liquid

7. The least count of digital Vernier callipers is: (RWP. GI, LHR. GII)
(A) 0.01mm (B) 0.001mm (C) 0.1mm (D) 1mm

8. Instrument which is most suitable to measure the internal diameter of test tube is: (DGK. GI, BWP. GII, SWL. GI)
(A) Meter rod (B) Vernier Callipers (C) Screw gauge (D) Measuring Tape

9. The least count of metre rod is: (RWP. G II, 2015)
(A) 1mm (B) 0.01m (C) 0.01cm (D) 0.01mm

10. What is the least count of Mechanical Stop Watch? (BWP. G I, 2015)
(A) 0.1s (B) 0.01s (C) 0.001s (D) 0.0001s

11. The number of significant figures in 0.00580km is: (RWP. G II, 2014)
(A) 5 (B) 4 (C) 3 (D) 2

Answers

1.	5000 ng	**2.**	10^{-6}m	**3.**	1cm^3	**4.**	2×10^{-4}s
5.	10^9 g	**6.**	Volume	**7.**	0.01mm	**8.**	Vernier Callipers
9.	1mm	**10.**	0.1s	**11.**	3		

☆ **Give short answer to the following questions.**

1. What is meant by prefixes? (SWL. GI & GII, DGK. GII)

Ans. Prefixes are the words or letters added before a unit and stand for the multiples or sub-multiples of that unit. For example, kilo, mega, milli, micro, etc.

2. Estimate your age in seconds. (LHR. GI, FBD. GII, DGK. GII)

Sol. 15 years = Age
1 year = 12 months
1 year = 365 days
1 year = 8760 hours
1 year = 525,600 minutes
1 year = 525600×60 = 31,536,000 sec
15 years = 15 × 315, 36000 sec
15 year = 473,040,000 sec

3. Express in scientific notation: 0.00580 km , 210.0 g (FBD. GI)

Sol. 0.00580 km = 5.80×10^{-3} km
210.0g = 2.1×10^2 g

4. In Physics what is importance of scientific notation in writing quantities. (SGD. GI)

Ans. In physics, scientific notation saves writing down or interpreting large numbers of zeros.

5. Write in Scientific Notation: (i) 100.8 sec (ii) 0.00580 km (BWP. GI)

Ans.(i) 100.8 sec $= 1.008\times10^2$ sec **(ii)** 0.00580 km $= 5.80\times10^{-3}$ km

6. What is meant by vernier constant? (LHR. GII, MLN. GII, FBD. GII, GRW. GI)

Ans. The difference between one small division on main scale division and one vernier scale division is 0.1 mm. It is called least count (LC) of the vernier callipers or vernier constant.

$$\text{Least count of vernier callipers} = \frac{\text{Smallest reading on the main scale}}{\text{Number of divisions on vernier scale}}$$

7. What do you understand by the zero error of a measuring instrument? (LHR. GII, SWL. GII)

Ans. By closing the jaws of measuring device, if the zero line of one scale (vernier scale) coincides with the zero line of its main scale (other scale) then there is no zero error. But zero error will exist if the zero line of one scale (vernier scale) is not coinciding with the zero of other scale (main scale). Zero error will be positive if zero line of one scale (vernier scale) is on the right side of the zero of other scale (main scale) and will be negative if zero line of one scale (vernier scale) is on the left side of zero of the other scale (main scale).

8. What is meant by zero error and zero correction? (GRW. GI)

Ans. Zero error: If the zero of the main scale does not coincide with the zero of the vernier scale, when the jaws closed there is zero error in the instrument.

Zero correction: To remove the error in the instrument is called zero correction.

9. Why a screw gauge measures more accurately than a vernier callipers? (GRW. GII, BWP. GI, MLN. GI)

Ans. The instrument, screw gauge is more precise than vernier callipers because the least count of vernier calliper is 0.01cm while the least count of screw gauge is 0.001cm.

10. How a digital stop watch can be used? (GRW. GII, FBD. GI)

Ans. The stopwatch starts when the knob is pressed one. When pressed second time, it stops the watch while the third press brings the needle back to zero position.

11. Define meter rod and also write its least count. (SGD. GII, BWP. GII)

Ans. Meter rod: A metre rule is a length measuring instrument.

Least count: One millimeter is the smallest reading that can be taken using a metre rule and is called its least count.

12. Define least count. What is the least count of a meter rod? (RWP. GI, GRW. GI)

Ans. The smallest reading that can be measured from any instrument is called least count. The least count of metre rod is 1mm.

13. Write the use of physical balance in physics in short. (DGK. GI)

Ans. A physical balance is used in the laboratory to measure the mass of various objects by comparison.

14. Differentiate between Mechanical Stop Watch and Digital Stop Watch. (BWP.GI)

Ans. Mechanical stopwatch: A machinal stopwatch can measure a time interval up to minimum 0.1 second.

Digital stopwatch: Digital stopwatch is commonly used in laboratories can measure a time interval as small as $\frac{1}{100}$ second or 0.01 second.

15. Define least count of screw gauge. (DGK. GI)

Ans. Least count of screw gauge: Least count of screw gauge can be found as given below.

$$\text{Least count} = \frac{\text{Pitch}}{\text{Number of divisions on circular scale}}$$

$$\text{Least count} = \frac{1\text{mm}}{100} = 0.01\text{mm}$$

Least count = 0.01mm = 0.001cm.

Least count of the screw gauge is 0.01 mm or 0.001 cm.

16. What is meant by significant figures and how many significant figures are there in 0.027? (SWL. GI, RWP. GI, SWL. GII)

Ans. Significant figures: All the accurately known digits and the first doubtful digit in an expression are called significant figures.

Significant figure reflects the precision of a measured value of a physical quantity. In 0.027, there are two significant figures.

17. Write down two rules to find the significant digits in a measurement. (SGD. GI, MLN. GI)

Ans. 1. Non-zero digits are always significant.

2. Zero between two significant figures are also significant.

18. Round of 1.35 and 1.45. (DGK. GII)

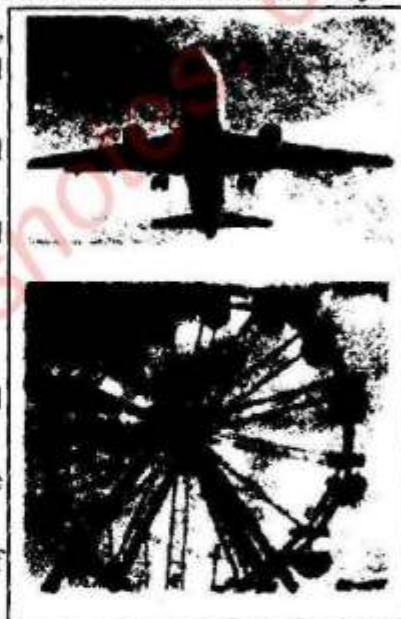
Ans. 1.35 rounded to 1.4, and 1.45 rounded to 1.4

KINEMATICS

STUDENTS LEARNING OUTCOMES

After studying this unit, the students will be able to:

- describe using examples how objects can be at rest and in motion simultaneously.
- identify different types of motion i.e. translatory, (linear, random and circular): rotatory and vibratory motions and distinguish among them.
- differentiate with examples between distance and displacement, speed and velocity.
- differentiate with examples between scalar and vector quantities.
- represent vector quantities by drawing.
- define the term speed, velocity and acceleration.
- plot and interpret distance - time graph and speed-time graph.
- determine and interpret the slope of distance-time and speed-time graph.
- determine from the shape of the graph, the state of a body.
  (i) at rest (ii) Moving with constant speed.
  (iii) Moving with variable speed.

- calculate the area under speed-time graph to determine the distance traveled by the moving body.
- derive equations of motion for a body moving with a uniform acceleration in a straight line using graph.
- solve problems related to uniformly accelerated motion using appropriate equations.
- solve problems related to freely falling bodies using $10 ms^{-2}$ as the acceleration due to gravity.

Conceptual Linkage

This unit is built on
Force and Motion –Science-IV
This chapter leads to:
Motion and force –Physics- XI

INVESTIGATION SKILL:

- demonstrate various types of motion so as to distinguish between translatory, rotatory and vibratory motions.
- measure the average speed of a 100m sprinter.

SCIENCE, TECHNOLOGY AND SOCIETY CONNECTION:

- list the effects of various means of transportations and their safety issues.
- the use of mathematical slopes (ramps) of graphs or straight lines in real life applications.
- interpret graph from newspaper, magazine regarding cricket and weather etc.

Major Concepts:

2.1 Rest and motion
2.2 Types of motion (Translatory, rotatory, vibratory)
2.3 Terms associated with motion;
- Position
- Distance and displacement
- Speed and velocity
- Acceleration

2.4 Scalars and vectors
2.5 Graphical analysis of motion;
- Distance-time graph
- Speed-time graph

2.6 Equations of motion;
- $S = vt$
- $v_f = v_i + at$
- $S = v_it + \frac{1}{2}at^2$
- $v_f^2 - v_i^2 = 2aS$

2.7 Motion due to gravity

The first thing concerning the motion of an object is its kinematics. Kinematics is the study of motion of an object without discussing the cause of motion, scalar and vector quantities, the relation between displacement, speed, velocity and acceleration; linear motion and equations of motion.

2.1 Rest And Motion

Q1. What is kinematics? Define rest and motion with examples. Discuss the state of rest or motion of a body is relative.

Ans: Kinematics: Kinematics is the study of motion of an object without discussing the cause of motion.

Rest: A body is said to be at rest, if it does not change its position with respect to its surroundings.

Example No 1: A book, placed on the table is an example of rest. Because it does not change its position.

Example No 2: Trees and streetlights around the roads are the examples of rest. Both do not change their positions.

Meaning of surroundings: Surrounding are the places in neighbourhood of any object, where various objects are present.

Motion: A body is said to be in motion, if it changes its position with respect to its surroundings.

Example No 1: A bus moving on a road is an example of motion.

Example No 2: A running boy in the street is an example of motion.

State of rest or motion of a body is relative.

The state of rest or motion of a body is relative.

Explanation: A passenger sitting in a moving bus is at rest because he/she is not changing his/her position with

Figure 2.1: The passengers in the bus are also moving with it.

respect to other passengers or objects in the bus.

But to an observer outside the bus, the passenger and the objects inside the bus are in motion.

2.2 Types of motion

Q2. Into how many types motion is divided? Write an explanatory note with examples.

Ans: Types of motion:

The motion of bodies can be divided into three types.

(1) Translatory motion (linear, random and circular)
(2) Rotatory motion.
(3) Vibratory motion (to and fro motion)

(1) Translatory motion:

Translatory motion is a type of motion in which a body moves along a line without any rotation. This line may be straight or curved.

Example No 1.

A car moving in a straight line has translational motion.

Example No 2.

An aeroplane moving straight is an example of translational motion.

Example No 3.

In the given figure the object moves along a curved path without rotation. This is the translational motion of the object.

Figure 2.3: Translatory motion of an object along a curved path.

Example No 4.

Riders moving in a ferris wheel are in translational motion. Their motion is in a circle without rotation.

Figure 2.4: Translatory motion of riders in Ferris wheel.

Types of translatory motions:

Translatory motions are divided into three types.

(i) Linear motion **(ii)** Circular motion
(iii) Random motion

(i) Linear motion: Straight line motion of a body is known as its linear motion.

Examples:

1. The motion of objects such as a car moving on a straight and level road is linear motion.
2. Aeroplanes flying straight is an example of linear motion.

3. The object falling vertically down is an example of linear motion.

Figure 2.2: A car and an aeroplane moving along a straight line are in linear motion.

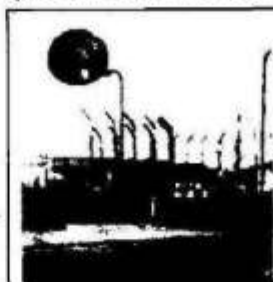



Figure 2.5: Linear motion of the ball falling down.

(ii) Circular motion:

The motion of an object in a circular path is known as circular motion.

Figure 2.6: A stone tied at the end of a string moves in a circle.

Example No 1: A stone tied at the end of a string can be made to whirl. The stone as shown in given figure moves in a circle and thus has circular motion.

Example No 2: The Given figure shows a toy train moving on a circular track.

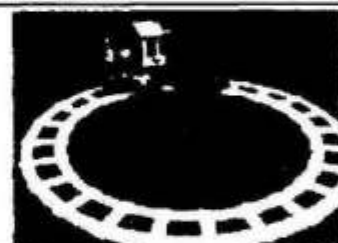



Figure 2.7: A toy train moving on a circular track

Example No 3: A bicycle or a car moving along a circular track possesses circular motion.

Example No 4: The riders in a moving ferris wheel have circular motion.

Example No 5: Motion of the Earth around the Sun is also the example of circular motion.

(iii) Random motion:

The disordered or irregular motion of an object is called random motion.

Example No 1: The motion of insects and birds is random motion.

Example No 2: The motion of dust or smoke particles in the air is also random motion.

Example No 3: Zig zag motion of the molecules of gases and liquids is called random. It is also called Brownian motion. This movement is also shown in figure.

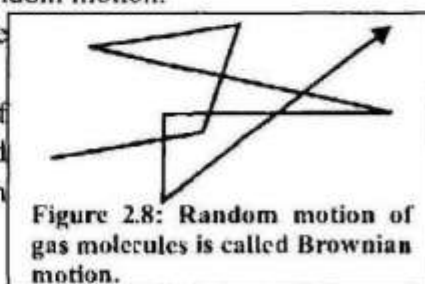



Figure 2.8: Random motion of gas molecules is called Brownian motion.

(2) Rotatory motion:

The spinning motion of a body about its axis is called rotatory motion.

Example No 1: The top is shown in a given figure. The top spins about its axis passing through it and thus it possesses rotatory motion.

An axis is a line around which a body rotates.

Example No 2: The type of motion of a bicycle wheel about its axis and a steering wheel are the examples of rotatory motion.

Example No 3: The motion of the Earth about its own axis is rotatory motion.

Example No4: The rotation of a football on a vertical finger is an example of rotatory motion. As shown in the figure.

Fig 2.9: Rotatory motion

Difference between circular and rotatory motion:

In circular motion, the point about which a body goes around, is outside the body. In rotatory motion, the line, about which a body moves is passing through the body itself.

Vibratory motion:

To and fro motion of a body about its mean position is known as vibratory motion.

Example No 1: Consider the motion of a baby in a swing as shown in the given figure. It moves back and forth about its mean position. The motion of the baby repeats from one extreme to the other extreme with the swing.

Example No 2: The pendulum of the clock has vibratory motion. The movement of this pendulum can be shown in the given figure.

Figure 2.10: Vibratory motion of a child and a Swing

Figure 2.11: Vibratory motion of the pendulum of a clock.

Example No 3: A baby in a cardle moving to and fro, about its mean position. This is an example of vibratory motion.

Example No 4: Up and down movement of the children in a see-saw is an example of vibratory motion.

Examples No 5: To and fro motion of the hammer of a ringing electric bell is an example of vibratory motion.

Example No 6: The motion of the string of a sitar is an example of vibratory motion.

Figure 2.12: Vibratory motion of children in a see-saw.

MINI EXERCISE:

1. ***When a body is said to be at rest?***

Ans: A body is said to be at rest when it does not change its position.

2. ***Give an example of a body that is at rest and is in motion at the same time.***

Ans: A passenger sitting in a moving bus is at rest because he/she is not changing his/her position with respect to other passengers or objects in the bus. But to an observer outside the bus, the passengers and the objects inside the bus are in motion.

3. ***Mention the type of motion in each of the following:***

(i) **A ball moving vertically upward.**

Ans: Linear motion.

(ii) **A child moving down a slide.**
Ans: **Linear motion.**
(iii) **Movement of a player in a football ground.**
Ans: **Random motion.**
(iv) **The flight of a butterfly.**
Ans: **Random motion.**
(v) **An athlete running in a circular track.**
Ans: **Circular motion.**
(vi) **The motion of a wheel.**
Ans: **Circular motion.**
(vii) **The motion of a cradle.**
Ans: **Vibratory motion.**

2.3 Scalars And Vectors

Q3. Define scalars and vectors quantities. Also give examples of them.

Ans: Scalar quantities: The physical quantities which are described completely by its magnitude only called scalars. OR

A scalar quantity is described completely by its magnitude only.

Meaning of magnitude: The magnitude of a quantity means its numerical value with an appropriate unit such as 2m, 40kg, 2s etc.

Examples: Mass, length, time, speed, volume, work and energy are examples of scalar quantities.

Vector quantities:

A vector can be described completely by magnitude along with its direction. **OR**

Such physical quantities which can be described completely by magnitude along with direction are called vectors.

Examples:

Examples of vectors are velocity, displacement, force, momentum, torque etc.

Importance of direction for vectors:

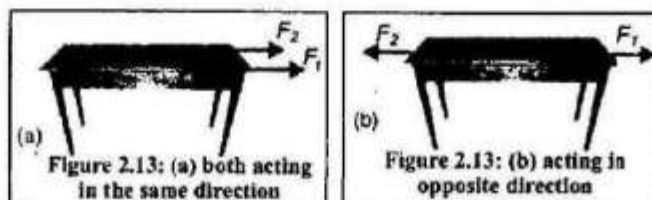
It would be meaningless to describe vectors without direction.

For example, distance of a place from reference point is insufficient to locate that place. The direction of that place from reference point is also necessary to locate it.

Explanation of vectors by a simple case: Consider a table as shown in given figure. Two forces F_1 and F_2 are acting on it.

Suppose these two forces F_1 and F_2 are acting on opposite directions as shown in given figure.

Figure 2.13: (a) both acting in the same direction

Figure 2.13: (b) acting in opposite direction

Surely the two situations differ from each other. Both situations differ due to the

direction of the forces acting on the table.

Thus the description of a force would be incomplete if direction is not given.

Walking of a person to a specific direction: When a person is walking at the rate of $3kmh^{-1}$ towards north then it is an example of vector.

Q4. How a vector can be represented?

Ans: Vectors can be represented by following methods.

Method No 1: A vector is usually represented by a bold letter.

To differentiate a vector from a scalar quantity, It is generally used bold letters to represent vector quantity. Such as **F, a, d.**

Method No 2: Vectors can be represented by a bar or arrow over their symbols such as $\bar{F}, \bar{a}, \bar{d}$ or $\vec{F}$, $\vec{a}$ and $\vec{d}$.

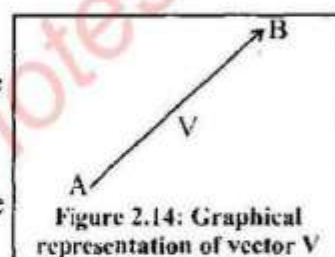
Method No 3:

Graphically a vector can be represented by a line segment with an arrow head as shown in the given figure.

⇒ The line AB with arrowhead at B represents a vector **V**.

⇒ The length of the line AB gives the magnitude of the vector **V** on a selected scale.

⇒ Direction of the line from A to B gives the direction of the vector **V**.

Figure 2.14: Graphical representation of vector V

Examples 2.1 Represent a force of 80 N acting toward North of East.

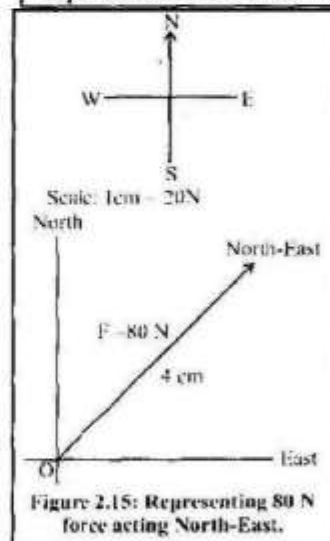
SOLUTION:

Step1: Draw two lines perpendicular to each other. Horizontal line represents East-West and vertical line represents North-South direction as shown in figure.

Step2: Select a suitable scale to represent the given vector. In this case we may take a scale which represents 20 N by 1 cm line.

Step3: Draw a line according to the scale in the direction of the vector. In this case, draw a line OA of length 4 cm along North-East.

Step4: Put an arrow head at the end of the line. In this case arrow head is at point A. Thus, the line OA will represent a vector i.e., the force of 80 N acting towards North-East.

Figure 2.15: Representing 80 N force acting North-East.

2.4 Terms Associated With Motion

Q5. (a) What is position? How it can be explained by a simple example.

(b) How will you differentiate between distance and displacement.

Ans: (a) Position:

Position means the location of a certain place or object from a reference point.

OR

The term position describes the location of a place or a point with respect to some reference point called origin.

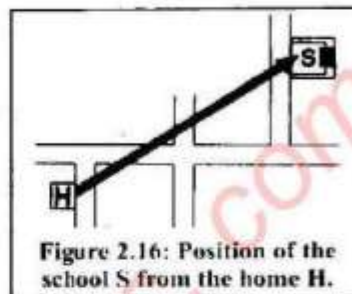



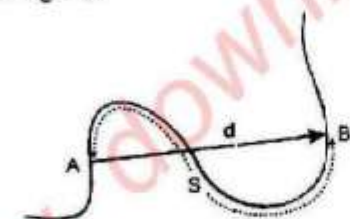
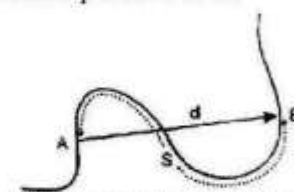
Figure 2.16: Position of the school S from the home H.

Explanation: If someone wants to describe the position of his/her school from home.

Let the school be represented by S and home by H as shown in the figure.

The position of the school from home will be the distance and is represented by a straight line HS in the direction from H to S as shown in given figure.

(b) Differences between distance and displacement.

Distance	Displacement
1. Length of a path between two points is called the distance between those points.	1. Displacement is the shortest distance between two points which has magnitude and direction.
2. It can be found out by given formula $S = v \times t$	2. It can be found out by given formula $d = v \times t$
3. It is a scalar quantity because it needs only magnitude to describe.	3. It is a vector quantity because it needs magnitude and direction to describe.
4. Let S be the length of the curved path between two points A and B on it. Then S is called the distance between points A and B, as shown in figure. **Figure 2.17: Distance S (dotted line) and displacement d (normal line) from points A to B.**	4. Given figure shows a body which moves from point A to point B in the curved path. Join points A and B by a straight line. The Line AB gives the shortest distance between point A and B, called displacement. It is represented by d. This shortest distance has magnitude (d) and direction from point A to B. **Figure 2.17: Distance S (dotted line) and displacement d (normal line) from points A to B.**

Q6. (a) What is speed? Give examples. Write formula and unit of speed.

(b) Define variable and uniform speed. Also give examples.

Ans: (a) Speed: The distance covered by an object in unit time is called its speed.

Unit time: Unit time may be a second, an hour, a day or a year.

Example No 1: Falcon can fly at a speed of 200 kmh–1.

Example No 2: Cheetah can run at a speed of 70 km h^{-1}.

Formula:

Speed can be found out by following formula.

$$\text{Speed} = \frac{\text{distance covered}}{\text{time taken}}$$

$$v = \frac{s}{t}$$

In this formula S is the distance covered by the object, v is its speed and t is the time taken by it.

Unit: SI unit of speed is metre per second (ms^{-1}).

Scalar quantity: Speed is a scalar quantity because it needs magnitude only to describe.

DO YOU KNOW?
Which is the fastest animal on the Earth?

Falcon can fly at a speed of 200 kmh^{-1}.

Cheetah can run at a speed of 70 kmh^{-1}

(b) Variable speed:

A body has variable speed if it covers equal distances in unequal intervals of time however short the interval may be.

Example: Suppose a body covers 2km distance in half hour and again it covers 2km distance in one hour. It is clear, that this body covers equal distances in unequal intervals of time so its speed is called variable speed.

Uniform Speed: A body has uniform speed if it covers equal distances in equal intervals of time however short the interval may be. (OR)

If the speed of the body does not vary and has the same value then the body is said to posses uniform speed.

Example: Suppose a body covers 2km distance in half hour and again it covers 2km distance in next half hour it is clear, that body covers equal distances in equal intervals of time so its speed is called uniform speed.

Q7. (a) Define velocity and give examples. Write its formula and unit also.
(b) How uniform and variable velocity can be defined? Give examples

Ans: (a) Velocity: The rate of displacement of a body is called its velocity.

Example: A body covers 2km distance towards north it is its velocity.

The velocity tells us not only the speed of a body but also its direction of motion.

Formula:

$$\text{Velocity} = \frac{\text{displacement}}{\text{time taken}}$$

$$v = \frac{d}{t}$$

Here d is the displacement of the body moving with velocity v in time taken t.

Unit: SI unit of velocity is the same as speed i.e. metre per second (ms^{-1}).

Vector quantity: Velocity is a vector quantity because it needs magnitude and direction for complete description.

Variable Velocity: A body has variable velocity if its speed or direction is changing.

Example No 1: Suppose a car is moving on a linear road, it covers 2km distance in 20 minutes and again covers 3km distance in 20 minutes. The speed of the body varies therefore having variable velocity.

Example No 2: A body is moving on a circular path has variable velocity. The body changes its direction constantly during the motion on a circular track during the motion on a circular track.

Uniform velocity: A body has uniform velocity if it covers equal displacement in equal intervals of time however short the interval may be.

(OR)

If the speed and direction of a body does not change, then it posses uniform velocity.

Example No 1: A paratrooper attains a uniform velocity also called terminal velocity with which it comes to ground.

Example No 2: Suppose a body covers 2km distance towards north in 10 minutes. It again covers 2km distance towards north in next 10 minutes. It is clear that the speed and direction of the body do not change so body has uniform velocity.

DO YOU KNOW?

A paratrooper attains a uniform velocity called terminal velocity with which it comes to ground.

DO YOU KNOW?

A motorway speed camera

A LIDAR gun is light detection and ranging speed gun. It uses the time taken by laser pulse to make a series of measurements of a vehicle's distance from the gun. The data is then used to calculate the vehicle's speed.

Important Note:

The uniform velocity of the body during any interval of time has the same magnitude and direction.

Example 2.2 ***A sprinter completes its 100 metre race in 12 seconds. Find its average speed.***

Solution: Total distance = 100m

Total time taken = 12s

$$\text{Average speed} = \frac{\text{Total distance moved}}{\text{Total time taken}} = \frac{100\text{m}}{12\text{s}} = 8.33\,\text{ms}^{-1}$$

Thus the speed of the sprinter is 8.33 ms^{-1}.

Example 2.3 ***A cyclist completes half round of a circular track of radius 318 m in 1.5 minutes. Find its speed and velocity.***

Solution: Radius of track r = 318m

Time taken t = 1min. 30 s = 90 s

Distance covered $= \pi \times \text{radius}$

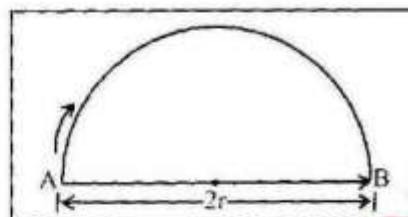
$= 3.14 \times 318\ \text{m} = 999\ \text{m}$

Displacement $= 2r$

$= 2 \times 318\ \text{m} = 636\ \text{m}$

Speed $= \dfrac{\text{distance}}{\text{time}}$

Speed $= \dfrac{999\ \text{m}}{90\ \text{s}} = 11.1\ \text{ms}^{-1}$

Velocity $= \dfrac{\text{displacement}}{\text{time taken}} = \dfrac{636\ \text{m}}{90\ \text{s}} = 7.07\ \text{ms}^{-1}$

Thus speed of the cyclist is 11.1 ms^{-1} along the track and its velocity is about 7.1 ms^{-1} along the diameter AB of the track.

USEFUL INFORMATION:
Acceleration of a moving object is in the direction of velocity if its velocity is increasing. Acceleration of the object is opposite to the direction of velocity if its velocity is decreasing.

Q8. (a) Define acceleration, give example. Write its formula and unit.
(b) Define variable and uniform acceleration.
(c) Define positive and negative acceleration also give examples.

Ans: (a) Acceleration: Acceleration is defined as the rate of change of velocity of a body.

Reason of acceleration: In many cases the velocity of a body changes due to a change either in its magnitude or direction or both. The change in the velocity of a body causes acceleration in it.

Example No 1: Acceleration of a moving object is in the direction of velocity if its velocity is increasing.

Example No 2: Acceleration of the object is opposite to the direction of velocity if its velocity is decreasing.

Formula: Acceleration can be found out by given formula.

$$\text{Acceleration} = \frac{\text{Change in velocity}}{\text{time taken}}$$

$$\text{Acceleration} = \frac{\text{final velocity} - \text{initial velocity}}{\text{time taken}} \quad = \mathbf{a} = \frac{\mathbf{v_f} - \mathbf{v_i}}{t}$$

Here **a** is the acceleration, $\mathbf{v_i}$ is the initial velocity, $\mathbf{v_f}$ is the final velocity and t is the time taken.

Unit: SI unit of acceleration is metre per second per second or ms^{-2}.

(b) Variable acceleration:

A body has variable acceleration if it has equal changes in velocity in unequal

intervals of time however short the interval may be.

Explanation: In equation $a = \frac{v_f - v_i}{t}$, (a) is the average acceleration of a body during time t. However, if time is divided into many small intervals of time, then the rate of change of velocity during these intervals may not be same. Thus the acceleration of the body would be changing.

Uniform acceleration: A body has uniform acceleration if it has equal changes in velocity in equal intervals of time however short the interval may be.

Explanation: The acceleration would remain uniform if the rate of change of velocity during time intervals is constant.

(c) Positive acceleration:

Acceleration of a body is positive if its velocity increases with time.

The direction of this acceleration is the same in which the body is moving without change in its direction.

Example: If a car is moving in a straight line and driver presses accelerator the velocity of the car will start increase having positive acceleration.

Negative Acceleration:

Acceleration of a body is negative if velocity of the body decreases.

The direction of negative acceleration is opposite to the direction in which body is moving.

"Negative acceleration is also called deceleration or retardation."

Example: If a car is moving in a straight line and the driver applies brakes, the velocity will start to decrease. So, acceleration will be negative and will opposite to the direction.

Example 2.4 ***A car starts from rest. Its velocity becomes 20 ms^{-1} in 8 s. Find its acceleration.***

Solution: Initial velocity v_i = $0 ms^{-1}$

Final velocity v_f = $20 ms^{-1}$

Time taken t = 8 s

as $a = \frac{v_f - v_i}{t}$

or $a = \frac{20ms^{-1} - 0ms^{-1}}{8s}$, $a = 2.5\ ms^{-2}$

Thus the acceleration of the car is $2.5\ ms^{-2}$.

Example 2.5 ***Find the retardation produced when a car moving at a velocity of 30 ms^{-1} slows down uniformly to 15 ms^{-1} in 5s.***

Solution: Initial velocity v_i = $30\ ms^{-1}$

Final velocity v_f = $15\ ms^{-1}$

Change of velocity = $v_f - v_i$

= $15\ ms^{-1} - 30\ ms^{-1} = -15\ ms^{-1}$

Time taken $t = 5\,s$

$a = ?$

as acceleration $a = \dfrac{\text{change in velocity}}{\text{time interval}}$

or $a = \dfrac{-15ms^{-1}}{5s} = -3ms^{-2}$

Since negative acceleration is called as deceleration. Thus deceleration of the car is $3\ ms^{-2}$.

2.5 Graphical analysis of motion

Q9. Define following.

Graph, Variables, Independent variable, Dependent variable.

A graph may also be used in every day life to show year-wise growth/decline of export, month-wise rainfall, a patient's temperature record or score of a team in a cricket match and so on.

Export of rice from 2001-2005

Runs scored by a cricket team.

Ans: Graph:

Graph is a pictorial way of presenting information about the relation between various quantities.

Variables:

The quantities between which a graph is plotted are called variables.

Independent Variables:

A quantity which we can change with our wishes is called independent variable.

Dependent Variables:

The quantity which changes due to change in independent variable is called dependent variables.

(OR)

The quantity whose value varies with the independent quantity.

Q10. (a) How distance - time graph is plotted? For what purpose it is used?

(b) Plot distance-time graph when the object is at rest, plot distance-time graph when the object is moving with constant speed.

Ans: (a) Distance-time graph:

It is useful to represent the motion of objects using graphs.

Distance and displacement: The terms distance and displacement are used interchangeably when the motion is in a straight line.

Speed and velocity:

If the motion is in a straight line then speed and velocity are used interchangeably.

The axis of time:

In the distance - time graph, time is taken along horizontal axis.

Axis of distance: In the distance - time graph vertical axis shows the distance covered by the object.

(b) Distance-time graph when object is at rest:

In the graph as shown in the given figure the distance moved by the object with time is zero. That is, the object is at rest.

Figure 2.18: Distance-time graph when the object is at rest

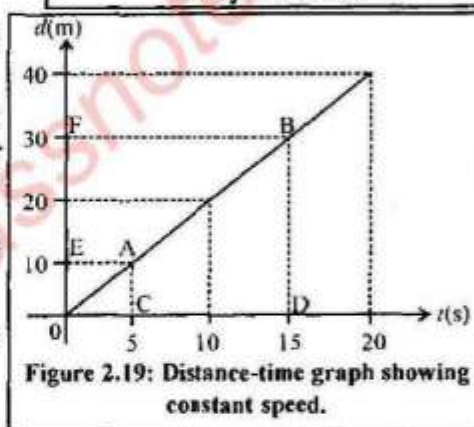
Speed of the object: A horizontal line parallel to time axis on a distance - time graph shows that speed of the object is zero.

Distance-time graph when object is moving with constant speed:

The speed of an object is said to be constant if it covers equal distances in equal intervals of time.

Figure 2.19: Distance-time graph showing constant speed.

Shape of graph: The distance-time graph as shown in the given figure is a straight line.

Speed of the object: The slope of the graph gives the speed of the object.

Consider two points A and B on the graph:

Speed of the object = Slope of line AB.

$$\text{Speed of object} = \frac{\text{distance EF}}{\text{time CD}}$$

$$\text{Speed of the object} = \frac{20}{10} = 2\text{ms}^{-1}$$

The speed found from the graph is 2ms^{-1}.

Q11. Plot the distance time graph when the object is moving with variable speed. Also find out its speed at any instant.

Ans: When an object does not cover equal distances in equal intervals of time then its speed is not constant.

Shape of graph: In this case the distance-time graph is not a straight line as shown in the given figure.

Determination of slope: The slope of the curve at any point can be found from the slope of the tangent at that point.

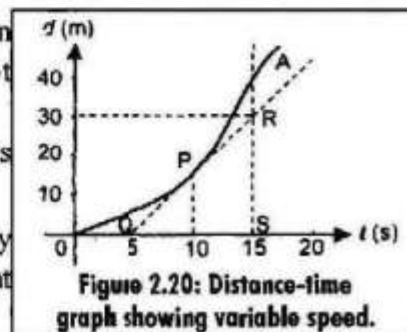



Figure 2.20: Distance-time graph showing variable speed.

For example:

Slope of the tangent at $P = \frac{RS}{QS}$

Value of speed at point P:

$$\text{Speed} = \frac{30\,\text{m}}{10\,\text{s}} = 3\text{ms}^{-1}.$$

The speed of the object at P is 3 ms^{-1}.

Relation of speed and slope:

⇒ The speed is higher at instants when slope is greater.

⇒ The speed is zero at instants when slope is horizontal.

Example 2.6 ***Given Figure shows the distance-time graph of a moving car. From the graph, find***

(a) the distance car has travelled.

(b) the speed during the first five seconds.

(c) average speed of the car.

(d) speed during the last 5 seconds.

Figure 2.21: Distance-time graph of a carin example 2.6.

Solution:

(a) Total distance travelled = 40 m

(b) Distance travelled during first 5 s is 35 m

$$\therefore \text{Speed} = \frac{35\,\text{m}}{5\,\text{s}}$$

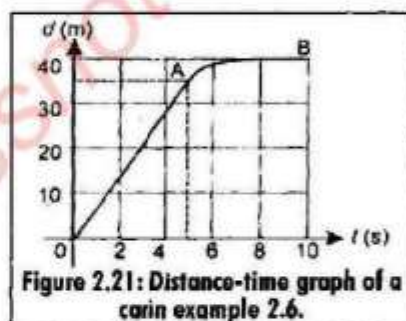
$$\text{Speed} = 7\text{ms}^{-1}$$

(c) $$\text{Average speed} = \frac{40\,\text{m}}{10\,\text{s}}$$

$$\text{Average speed} = 4\text{ms}^{-1}$$

(d) Distance moved during the last 5s = 5m

$$\text{Speed} = \frac{5\,\text{m}}{5\,\text{s}}$$

$$\text{Speed} = 1\text{ms}^{-1}$$

Q12. What is speed-time graph? Plot the graph when object is moving with constant speed and also plot a graph when object is moving with uniformly changing speed.

Ans: Speed - time graph:

In a speed-time graph, time is taken along x-axis and speed is taken along y-axis.

Object moving with constant speed: A straight line graph which will parallel to time

axis represents constant speed of the object.

Figure 2.22: Speed-time graph showing constant speed

Explanation:

When the speed of the object is constant (4m/s) with time, then the speed- time graph will be a horizontal line parallel to time-axis along x-axis as shown in figure.

Object moving with uniformly changing speed (uniform acceleration):

Let the speed of an object be changing uniformly. In such a case speed is changing at constant rate.

Figure 2.23: Graph of an object moving with uniform acceleration.

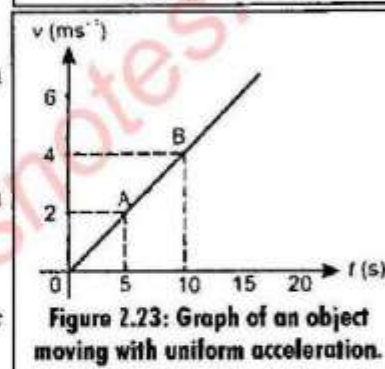
Shape of the graph:

In this case the shape of the graph would be a straight line such as shown in the given figure.

Meaning of straight line:

A straight line means that the object is moving with uniform acceleration.

Slope of the graph:

Slope of the line in the graph gives the magnitude of its acceleration.

EXAMPLE 2.7

Find the acceleration from speed-time graph shown in given figure.

Solution: On the graph in given figure point A gives speed of the object as 2 ms^{-1} after 5 s. And point B gives speed of the object as ms^{-1} after 10 s.

as acceleration = slope of AB

Where slope = change in velocity/time interval

$$\therefore \text{ acceleration } = \frac{4\,ms^{-1} - 2ms^{-1}}{10\,s - 5s}$$

$$\text{acceleration} = \frac{2ms^{-1}}{5s} = 0.4ms^{-2}$$

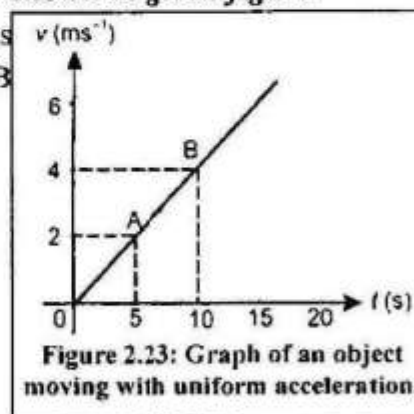



Figure 2.23: Graph of an object moving with uniform acceleration.

Speed-time graph in figure 2.23 gives acceleration of the object as 0.4 ms^{-2}.

EXAMPLE 2.8

Find the acceleration from speed-time graph shown in given figure.

Solution:

The graph in given figure shows that the speed of the object is decreasing with time. The speed is 4 ms^{-1} after 5 s and becomes 2 ms^{-1} after 10 s.

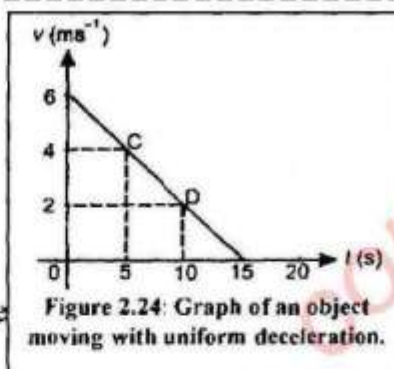
as acceleration = slope of CD

$$\text{acceleration} = \frac{2\text{ms}^{-1} - 4\text{ms}^{-1}}{10\text{s} - 5\text{s}}$$

$$\text{acceleration} = -\frac{2\text{ms}^{-1}}{5\text{s}}$$

$$= -0.4\text{ms}^{-2}$$

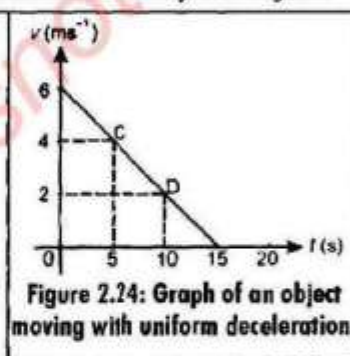
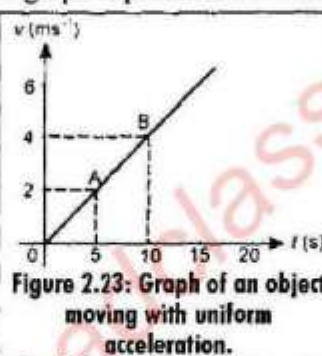
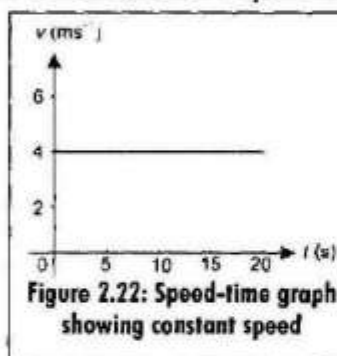
Figure 2.24: Graph of an object moving with uniform deceleration.

Speed-time graph in given figure gives negative slope. Thus the object has deceleration of 0.4 ms^{-2}.

Q13. How distance travelled by a moving object can be found out in a speed-time graph.

Ans: The area under a speed-time graph represents the distance travelled by the object.

Figure 2.22: Speed-time graph showing constant speed

Figure 2.23: Graph of an object moving with uniform acceleration.

Figure 2.24: Graph of an object moving with uniform deceleration.

Distance in the case of uniform motion: If the motion is uniform then the area can be calculated using appropriate formula for geometrical shapes represented by the graph.

EXAMPLE 2.9 ***A car moves in a straight line. The speed-time graph of its motion is shown in figure.***

From the graph, find

(a) Its acceleration during the first 10 seconds.

(b) Its deceleration during the last 2 seconds.

(c) Total distance travelled.

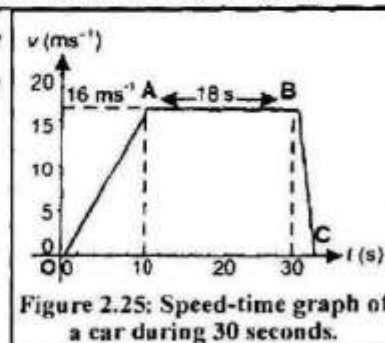
(d) Average speed of the car during its journey.

Figure 2.25: Speed-time graph of a car during 30 seconds.

Solution:

(a) Acceleration during the first 10 seconds:

$$\text{Acceleration} = \frac{\text{change in velocity}}{\text{time taken}}$$

$$a = \frac{16\,\text{ms}^{-1} - 0\,\text{ms}^{-1}}{10\,\text{s}}$$

$a = 1.6\ ms^{-2}$

(b) Acceleration during the last 2 seconds:

$$\text{Acceleration} = \frac{0\ ms^{-1} - 16\ ms^{-1}}{2\ s} \qquad a = -8\ ms^{-2}$$

(c) Total distance travelled:

distance = area under the graph (trapezium OABC)

$$S = \frac{1}{2}\text{(sum of parallel sides)} \times \text{height}$$

$$S = \frac{1}{2}(18\ s + 30\ s) \times (16\ ms^{-1})$$

$$S = \frac{1}{2}(48\ s) \times (16\ ms^{-1})$$

$$S = 384\ m$$

(d) $\text{Average speed} = \frac{\text{Total distance covered}}{\text{Time taken}} = \frac{384\ m}{30\ s}$

Average speed = $12.8\ ms^{-1}$

2.6 Equations of Motion

Q14. What are the types of equations of motion? What information these equations give?

Ans: There are three basic equations of motion for bodies moving with uniform acceleration.

(i) $v_f = v_i + at$ (ii) $S = v_i t + \frac{1}{2}at^2$
(iii) $2aS = v_f^2 - v_i^2$

Figure 2.26: Speed-time graph, Area under the graph gives the distance covered by the body.

(1) These equations relates initial velocity, final velocity, acceleration, time and distance covered by the moving body.

(2) To simplify the derivation of these equations. It is assumed that the motion is along a straight line.

(3) Only magnitude of displacements, velocities and acceleration are considered in these equations.

Graphical explanation: Consider a body moving with initial velocity (v_i) in a straight line with uniform acceleration **a**. its velocity (v_i)becomes (v_f) after time t. The motion of body is described by speed-time graph as shown in given figure by line AB.

Q15. How equations of motion can be proved with the help of speed-time graph. Prove all equations.

Ans: First equation of motion: Suppose a body is moving with initial velocity (v_i). After time (t) its velocity will becomes (v_f). The acceleration of the body is represented by (a.)

Figure: Speed-time graph, Area under the graph gives the distance covered by the body.

Speed-time graph: In speed-time graph motion of the body is shown in figure.

Slope of the line AB gives the acceleration (a) of the body.

Slope of line AB = a

$$a = \frac{BC}{AC} = \frac{BD - CD}{OD}$$

It is clear from the figure.

$BD = v_f$ = Final velocity
$CD = v_i$ = Initial velocity
$OD = t$ = time

So by putting all values

$$a = \frac{v_f - v_i}{t}$$

$$at = v_f - v_i$$

$$at + v_i = v_f$$

$$\boxed{v_f = v_i + at}$$

First equation of motion gives the relation between final velocity, initial velocity, acceleration and time.

Figure: Speed-time graph, Area under the graph gives the distance covered by the body.

Second equation of motion: Suppose a body is moving with initial velocity (v_i) after time (t) its velocity will be (v_f). the distance covered by the body is S. The acceleration of the body is represented by a.

Speed-time graph: In speed-time graph, the total distance S travelled by the body is equal to area OABD under the graph as shown in figure.

Total distance S = area of (rectangle OACD + triangle ABC)

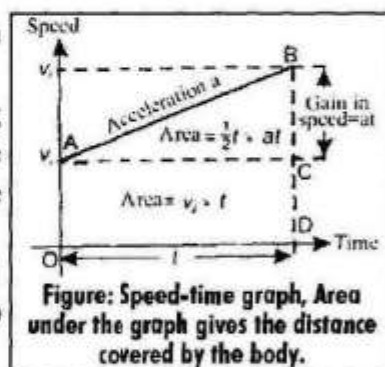
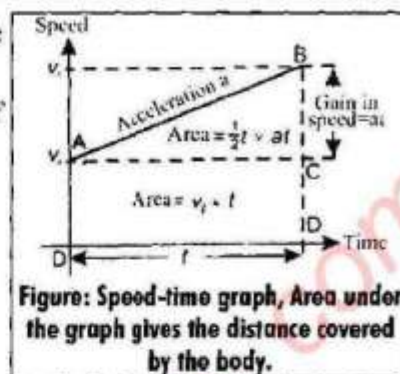
Area of rectangle OACD = OA × OD
$= v_i \times t$

Area of the triangle ABC = $\frac{1}{2}$ (AC × BC)
$= \frac{1}{2} t \times at$

Area of the triangle $= \frac{1}{2} at^2$

Since total area of OABD = area of rectangle OACD + Area of triangle ABC.

By putting values in the above equation we get;

$$S = v_i t + \frac{1}{2} at^2$$

So, second equation of motion has proved and shows the relationship of distance, initial velocity, time and acceleration.

Third equation of motion: Suppose a body is moving with initial velocity (v_i) after time (t) its final velocity will be v_f. The distance covered by the body is (S) The acceleration of the body is represented by (a).

Speed-time graph: In speed-time graph as shown in the figure, the total distance S travelled by the body is given by the total area OABD under the graph.

$$\text{Total area OABD} = S = \frac{OA + BD}{2} \times OD$$

or

$$2S = (OA + BD) \times OD.$$

Multiply both sides by $\frac{BC}{OD}$, we get: $\left(\frac{BC}{OD} = a\right)$

$$2S \times \frac{BC}{OD} = (OA + BD) \times OD \times \frac{BC}{OD}$$

$$2S \times \frac{BC}{OD} = (OA + BD) \times BC \quad ____ (1)$$

Putting the values in the above equation (1)

We get;

$$2S \times a = (v_f + v_i) \times (v_f - v_i)$$

According to formula:

$$(a + b)(a - b) = (a^2 - b^2)$$

$$\boxed{2aS = v_f^2 - v_i^2}$$

Example 2.10 ***A car travelling at 10 ms^{-1} accelerates uniformly at 2ms^{-2}. Calculate its velocity after 5 s.***

Solution:

$v_i = 10ms^{-1}$

$a = 2ms^{-2}$

$t = 5s$

$v_f = ?$

Using the Ist equation of motion we get;

$v_f = v_i + at$

$v_f = 10ms^{-1} + 2ms^{-1} \times 5s$

or $v_f = 20ms^{-1}$

The velocity of the car after 5 s is 20 ms^{-1}.

Example 2.11 ***A train slows down from 80 kmh^{-1} with a uniform retardation of 2 ms^{-2}. How long will it take to attain a speed of 20kmh^{-1}?***

Solution: $v_i = 80\ kmh^{-1}$

$$= \frac{80 \times 1000m}{60 \times 60s} = 22.2\ ms^{-1}$$

$v_f = 20\ kmh^{-1}$

$= \dfrac{20 \times 1000m}{60 \times 60 s}$

$= 5.6\ ms^{-1}$

$a = -2ms^{-1}$

$t = ?$

Using first equation of motion, we get;

$v_f = v_i + at$

or $t = \dfrac{v_f - v_i}{a}$

or $t = \dfrac{5.6(ms^{-1}) - 22.2(ms^{-1})}{-2ms^{-2}}$

or $t = 8.3\ s$

Thus the train will take 8.3 to attain the required speed.

USEFUL INFORMATION

- **To convert ms^{-1} to kmh^{-1}**

1ms = 0.001 km×3600h
= 3.6 kmh^{-1}

Thus multiply speed in ms^{-1} by 3.6 to get speed in kmh^{-1} e.g.,

20ms = 20×3.6 kmh
= 72 kmh^{-1}

- **To convert kmh^{-1} to ms**

$1kmh^{-1} \cdot \dfrac{1000m}{60 \times 60s} = \dfrac{10}{36} ms^{-1}$

Thus multiply speed in kmh^{-1} by $\dfrac{10}{36}$ to get speed in ms e.g.,

50kmh $= 50 \times \dfrac{10}{36} ms^{-1}$
= 13.88ms^{-1}

Similarly

- **To convert ms^{-2} to kmh^{-1}**

Multiply acceleration in ms^{-2} by {(3600×3600)/1000} = 12960 to get its value in kmh^{-2}.

- **To convert kmh^{-2} to ms^{-2}**

Divide acceleration in kmh^{-2} by 12960 to get its value in ms^{-2}.

Example 2.12 ***A bicycle accelerates at 1 ms–2 from an initial velocity of 4 ms–1 for 10 s. Find the distance moved by it during this interval of time.***

Solution: $v = 4ms^{-1}$

$a = 1ms^{-2}$

$t = 10s$

$S = ?$

By using second equation of motion, we get;

$S = vit + \frac{1}{2} at^2$

$S = 4ms^{-1} \times 10\ s + \frac{1}{2} \times 1\ ms^{-2} \times (10\ s)^2$

or $S = 40\ m + 50\ m = 90\ m$

Thus, the bicycle will move 90 metres in 10 seconds.

Example 2.13 ***A car travels with a velocity of 5 ms–1. It then accelerates uniformly and travels a distance of 50m. If the velocity reached is 15ms–1. Find the acceleration and the time to travel this distance.***

Solution: $v_i = 5ms^{-1}$

$S = 50m$

$v_f = 15ms^{-1}$

$a = ?$

$t = ?$

Putting values in the third equation of motion, we get

$2aS = v_f - v_i$

$\therefore\ 2a \times 50\ m = (15ms^{-1})^2 - (5ms^{-1})^2$

$(100\ m)\ a = (225 - 25)\ m^2s^{-2}$

$$a = \frac{200m^2s^{-2}}{100m}$$

or $a = 2\ ms^{-2}$

Using first equation of motion to find t, we get

$$v_f = v_i + at$$

$\therefore\quad 15ms^{-1} = 5ms^{-1} + 2ms^{-2} \times t$

$15ms^{-1} - 5ms^{-1} = 2ms^{-2} \times t$

or $2ms^{-2} \times t = 10\ ms^{-1}$

or $$t = \frac{10ms^{-1}}{2ms^{-2}}$$

time = 5 s

Thus the acceleration of the car is 2 ms^{-2} and it takes 5 seconds to travel 50 m distance.

2.7 Motion of freely falling bodies

Q16. What do you know about the motion of freely falling bodies? Also define gravitational acceleration.

Ans: Contribution of Galileo: Galileo was the first scientist who, notice that all the freely falling objects have the same acceleration, independent of their masses.

Galileo's Experiment: Galileo dropped various objects of different masses from the leaning tower of pisa.

He found all of them reach the ground at the same time.

Gravitational acceleration: The acceleration of a freely falling bodies is called gravitational acceleration. It is denoted by **g**.

Value of g:

On the surface of the Earth, the value of **g** is approximately $10ms^{-2}$.

⇒ For bodies falling freely g is positive.

⇒ For bodies, moving up g is negative.

Figure 2.27: Leaning Tower of Pisa

Example 2.14 ***A stone is dropped from the top of a tower. The stone hits the ground after 5 seconds. Find:***

(a) the height of the tower.

(b) the velocity with which the stone hits the ground.

EQUATIONS OF MOTION FOR BODIES MOVING UNDER GRAVITY

$$v_f = v_i + gt$$

$$h = v_i t + \frac{1}{2}gt^2$$

$$2gh = v_f^2 - v_i^2$$

Solution: Initial velocity v_i = 0

Gravitational acceleration $g = 10ms^{-2}$

$t = 5\ s$

$S = h = ?$

$v_f = ?$

(a) Applying the equation:

$h = v_i t + \frac{1}{2} g t^2$, we get

$h = 0 \times 5\ s + \frac{1}{2} \times 10\ ms^{-2} \times (5\ s)^2$

or $h = 0 + 125\ m$

$\therefore\ h = 125\ m$

(b) Applying the equation:

$v_f^2 - v_i^2 = 2gh$

$v_f^2 - (0)^2 = 2 \times 10\ ms^{-2} \times 125\ m$

$v_f^2 = 2500\ m^2 s^{-2}$

$\therefore\ v_f = 50\ ms^{-1}$

Thus the height of the tower is 125 metres and it will hit the ground with a speed of 50 ms^{-1}.

Example 2.15 ***A boy throws a ball vertically up. It returns to the ground after 5 seconds. Find***

(a) the maximum height reached by the ball.

(b) the velocity with which the ball is thrown up.

Solution: Initial velocity (upward) $v_i = ?$

Gravitational acceleration $g = -10\ ms^{-2}$

Time for up and down motion $t_0 = 5$

Velocity at maximum height $v_f = 0$

$S = h = ?$

As the acceleration due to gravity is uniform, hence the time taken by the ball to go up will be equal to the time taken to come down = $\frac{1}{2} t_0$

or $t = \frac{1}{2} \times 5\ s = 2.5\ s$

(b) applying the 1st equation of motion we get:

$v_f = v_i + gt,$

$0 = v_i - 10\ ms^{-2} \times 2.5\ s$

$= v_i - 25\ ms^{-1}$

$\therefore\ v_i = 25 ms^{-1}$

(a) Applying the 2nd equation of motion we get;

$h = V_i t + \frac{1}{2} gt^2$

$h = 25\ ms^{-1} \times 2.5\ s - 10 ms^{-2} \times (2.5s)^2$

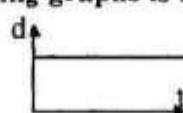
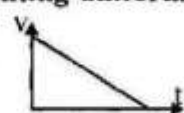
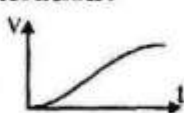
or $h = 62.5\ m - 31.25\ m = 31.25\ m$

Thus

The ball was thrown up with a speed of 25 ms^{-1}. and the maximum height the ball has reached is 31.25 m.

SUMMARY

- A body is said to be at rest, if it does not change its position with respect to its surroundings.
- A body is said to be in motion, if it changes its position with respect to its surroundings.
- Rest and motion are always relative. There is no such thing as absolute rest or

absolute motion.

- Motion can be divided into the following three type.
  - **Translatory motion.** In which a body moves without any rotation.
  - **Rotatory motion.** In which a body spins about its axis.
  - **Vibratory motion.** In which a body moves to and fro about its mean position.
- Physical quantities which are completely described by their magnitude only are known as scalars.
- Physical quantities which are described by their magnitude and direction are called vectors.
- Position means the location of a certain place or object from a reference point.
- The shortest distance between two points is called the displacement.
- The distance travelled in any direction by a body in unit time is called speed.
- If the speed of a body does not change with time then its speed is uniform.
- Average speed of a body is the ratio of the total distance covered to the total time taken.
- We define velocity as rate of change of displacement or speed in a specific direction.
- Average velocity of a body is defined as the ratio of its net displacement to the total time.
- If a body covers equal displacements in equal intervals of time, however small the interval may be, then its velocity is said to be uniform.
- The rate of change of velocity of a body is called acceleration.
- A body has uniform acceleration if it has equal changes in its velocity in equal intervals of time, however small the intervals may be.
- Graph is a pictorial way of describing information as to how various quantities are related to each other.
- Slope of the distance - time graph gives the speed of the body.
- Distance - time graphs provide useful information about the motion of an object. Slope of the displacement-time graph gives the velocity of the body.
- Distance covered by a body is equal to area under speed-time graph.
- Speed-time graph is also useful for studying motion along a straight line.
- The distance travelled by a body can also be found from the area under a velocity - time graph if the motion is along a straight line.
- Equations of motion for uniformly accelerated motion are:
  - $v_f = v_i + at$
  - $S = v_i t + \frac{1}{2} at^2$
  - $2aS = v_f^2 - v_i^2$

- When a body is dropped freely it falls down with an acceleration towards Earth. This acceleration is called acceleration due to gravity and is denoted by g. The numerical value of g is approximately 10 ms^{-2} near the surface of the Earth.

SOLVED QUESTIONS

2.1 Encircle the correct answer from the given choices.

(i) A body has translatory motion if it moves along a:
(a) straight line (b) circle (c) Line without rotation (d) curved path

(ii) The motion of a body about an axis is called:
(a) circular motion (b) rotatory motion (c) vibratory motion (d) random motion

(iii) Which of the following is a vector quantity?
(a) speed (b) distance (c) displacement (d) power

(iv) If an object is moving with constant speed then its distance-time graph will be a straight line:
(a) along time-axis (b) along distance-axis
(c) parallel to time-axis (d) inclined to time-axis

(v) A straight line parallel to time axis on a distance-time graph tells that the object is:
(a) moving with constant speed (b) at rest
(c) moving with variable speed (d) in motion

(vi) The speed-time graph of a car is shown in the figure, which of the following statement is true?

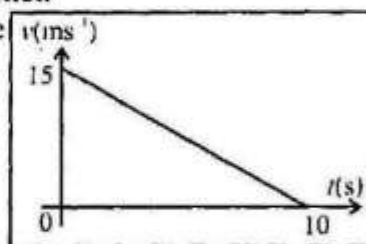
(a) car has an acceleration of 1.5 ms^{-2}
(b) car has constant speed of 7.5 ms^{-1}
(c) distance travelled by the car is 75 m
(d) average speed of the car is 15 ms^{-1}

(vii) Which one of the following graphs is representing uniform acceleration?

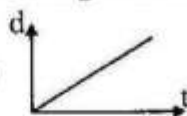
(viii) By dividing displacement of a moving body with time, we obtain:
(a) speed (b) acceleration (c) velocity (d) deceleration

(ix) A ball is thrown vertically upward. Its velocity at the highest point is:
(a) $-10ms^{-1}$ (b) zero (c) $10ms^{-2}$ (d) None of these

(x) A change in position is called:
(a) speed (b) velocity (c) displacement (d) distance

(xi) A train is moving at a speed of 36 kmh^{-1}. Its speed expressed in ms^{-1} is:
(a) 10 ms^{-1} (b) 20 ms^{-1} (c) 25 ms^{-1} (d) 30 ms^{-1}

(xii) A car starts from rest. It acquires a speed of 25 ms^{-1} after 20 s. The distance moved by the car during this time is:

(a) 31.25 m (b) 250 m (c) 500 m (d) 5000 m

Ans: (i) Line without rotation (ii) rotatory motion (iii) displacement
(iv) parallel to time-axis (v) moving with constant speed
(vi) car has an acceleration of 1.5 ms^{-2} (vii) [graph: d against t, straight line] (viii) velocity
(ix) zero (x) distance (xi) 10 ms^{-1} (xii) 250 m

2.2 Explain translatory motion and give examples of various types of translatory motion.

Ans: Translatory motion: The motion in which a body moves along a line without any rotation, is called translatory motion.
In translatory motion the line may be straight or curved.

Types of translatory motion: There are three types of translatory motion.

(a) Circular motion (b) Linear motion (c) Random motion

(a) Circular motion:

The motion of an object in a circular path is known as circular motion.

Examples: (i) A bicycle or a car moving along a circular track.
(ii) The riders in a moving ferris wheel have circular motion.

(b) Linear motion:

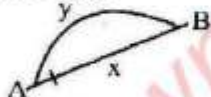
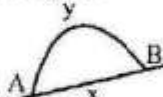
Straight line motion of a body is known as its linear motion.

Examples: (i) Aeroplane flying straight in air is an example of linear motion
(ii) Objects falling vertically down is an example of linear motion

(c) Random motion:

The disordered or irregular motion of an object is called random motion.

Examples:

(i) Motion of insects and birds is random motion.
(ii) The motion of dust or smoke particles in the air is random motion.

2.3 Differentiate between the following:

(i) Rest and motion. ***(ii) Circular motion and rotatory motion.***
(iii) Distance and displacement ***(iv) Speed and velocity.***
(v) Linear and random motion. ***(vi) Scalars and vectors***

Ans:

Rest	Motion
⇒ A body is said to be at rest, if it does not change its position with respect to its surroundings.	⇒ A body is said to be in motion, if it changes its position with respect to its surroundings.

⇒ Trees around the bank of the road are in rest position.	⇒ A moving bus on the road is in a state of motion.

Circular Motion	Rotatory Motion
⇒ The motion of an object in a circular path is known as circular motion. ⇒ Motion of the earth around the sun and motion of the moon around the earth are examples of circular motion.	⇒ The spinning motion of a body about its axis is called its rotatory motion. ⇒ The motion of the Earth about its own axis is rotatory motion. The type of motion of a bicycle wheel about its axis is also rotatory motio

Distance	Displacement
⇒ Length of a path between two points is called the distance between those points.	⇒ Displacement is the shortest distance, between two points which has magnitude and direction.
⇒ Distance is a scalar quantity because it can be completely described with the help of magnitude only.	⇒ Displacement is a vector quantity because it can be completely described with the help of magnitude and direction.
⇒ The value of distance can be found out by given formula. $S = v \times t$. ⇒ In the given figure the distance is represented by y.	⇒ The value of displacement can be derived by given formula. $d = v \times t$ ⇒ In the given figure the displacement is represented by x.

Speed	Velocity
⇒ The distance covered by an object in unit time is called its speed. ⇒ Speed can be calculated by given formula. $\text{Speed} = \frac{\text{distance covered}}{\text{time}}$ ⇒ Speed is a scalar quantity. Because it can be described completely by a magnitude only. ⇒ A man covers 20m distance in 5 sec. Its speed is $4ms^{-1}$.	⇒ The rate of displacement of a body is called its velocity. ⇒ Velocity can be calculated by given formula. $\text{Velocity} = \frac{\text{displacement}}{\text{time taken}}$ ⇒ Velocity is a vector quantity. Because it can be described completely by a magnitude and direction. ⇒ A man covers 20m distance in 5 sec towards North. Its velocity is $4ms^{-1}$ towards north.

Linear motion	Random motion
⇒ Straight line motion of a body is known as its linear motion. ⇒ Aeroplanes flying straight in air and objects falling vertically down are the examples of linear motion.	⇒ The disordered or irregular motion of an object is called random motion. ⇒ The motion of dust or smoke particles in the air is the example of random motion.

Scalars	Vectors
⇒ A scalar is described completely by its magnitude only. ⇒ Mass, length, time, speed, volume, work and energy are some examples of scalars.	⇒ A vector is described completely by magnitude and direction. ⇒ Velocity, displacement, force, momentum and torque are some examples of vectors.

2.4 Define the terms speed, velocity and acceleration.

Ans: Speed:

⇒ The distance covered by an object in unit time is called speed.

⇒ Speed can be calculated as $v = \frac{S}{t}$.

⇒ Unit of speed is metre per second (ms^{-1}).

⇒ It is a scalar quantity.

Acceleration:

⇒ Acceleration is defined as the rate of change of velocity of a body.

⇒ Acceleration can be calculated as.

$$\text{Acceleration} = \frac{\text{Change in velocity}}{\text{time taken}}$$

⇒ Unit of acceleration is metre per second per second (ms^{-2}).

⇒ It is a vector quantity.

Velocity:

⇒ The rate of displacement of a body is called its velocity.

⇒ Velocity can be calculated as $v = \frac{d}{t}$

⇒ Unit of velocity is metre per second (ms^{-1})

⇒ It is a vector quantity.

2.5 Can a body moving at a constant speed have acceleration?

Ans: Yes a body moving at a constant speed have acceleration if it changes its direction or moving in a circular path.

2.6 How do riders in a Ferris wheel possess translatory motion but not rotatory motion?

Ans: In circular motion the point about which a body goes around, is outside the body. In rotatory motion the line about which a body moves is passing through the body itself.

Riders in a ferris wheel have rotatory motion because the axis about which a rider moves is passing through the rider itself.

2.7 Sketch a distance-time graph for a body starting from rest. How will you determine the speed of a body from this graph?

Ans: Object is moving with constant speed.

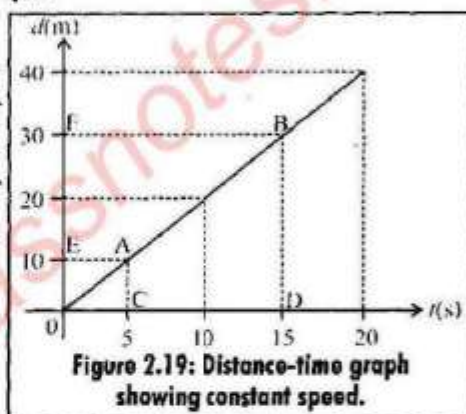
The speed of an object is said to be constant if it covers equal distances in equal intervals of time. The distance-time graph as shown in figure 2.19 is a straight line. It slope gives the speed of the object. Consider two points A and B on the graph:

Figure 2.19: Distance-time graph showing constant speed.

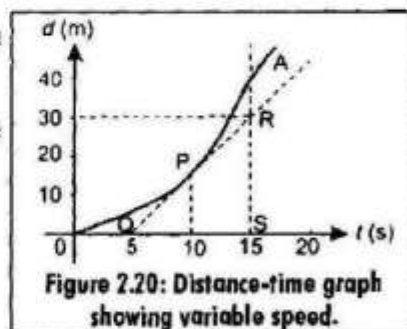
Speed of the object = Slope of line AB.

$$\text{Speed of object} = \frac{\text{distance EF}}{\text{time CD}}$$

$$\text{Speed of the object} = \frac{20}{10} = 2\text{ms}^{-1}$$

The speed found from the graph is 2ms^{-1}.

2.8 What would be the shape of a speed - time graph of a body moving with variable speed?

Ans: When a body is moving with variable speed, the shape of its speed-time graph is not a straight line.

Figure 2.20: Distance-time graph showing variable speed.

2.9 Which of the following can be obtained from speed-time graph of a body?

(i) *Initial speed.* (ii) *Final speed.*

(iii) *Distance covered in time t.* (iv) *Acceleration of motion.*

Ans: All the given factors can be obtained from speed-time graph of a moving body.

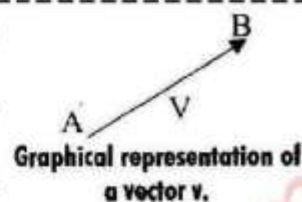
2.10 How can vector quantities be represented graphically?

Ans: Graphically a vector can be represented by a line segment with an arrow head. In

the given figure the line AB with arrowhead at B represents a vector **V**.

The length of the line AB gives the magnitude of the vector v on a selected scale.

While the direction of the line from A to B gives the direction of the vector **V**.

B
A V
Graphical representation of a vector v.

2.11 Why vector quantities cannot be added and subtracted like scalar quantities?

Ans: Scalars quantities are the quantities which can be described completely by magnitude while vectors quantities need direction and magnitude for their complete description.

The quantities having direction cannot be added and subtracted like scalar quantities.

2.12 How are vector quantities important to us in our daily life?

Ans: Vector quantities are important to us in our daily life because a vector can be described completely by magnitude along with its direction. Examples of vectors are velocity, displacement, force, momentum, torque, etc. It would be meaningless to describe vectors without direction. For example, distance of a place from reference point is insufficient to locate that place. The direction of that place from reference point is also necessary to locate it.

2.13 Derive equations of motion for uniformly accelerated rectilinear motion.

Ans: See question # 15.

2.14 Sketch a velocity - time graph for the motion of the body. From the graph explaining each step, calculate total distance covered by the body.

Ans: See question # 12 & 13.

SOLVED PROBLEMS

2.1 A train moves with a uniform velocity of 36 kmh⁻¹ for 10 s. Find the distance travelled by it.

Data: Uniform velocity = v_{av} = $36\ kmh^{-1}$

$$= \frac{36\times1000}{60\times60} = \frac{360}{36}$$

Uniform Velocity = v_{av} = $10ms^{-1}$

Time = t = 10sec.

Required: Distance = ?

Formula: $S = v_{av} \times t$

Solution: By Putting values in the given equation, value of distance (S) can be obtained.

$S = 10 \times 10$

$\boxed{S=100m}$

Answer: The required distance (S) of the train is 100m.

2.2 A train starts from rest. It moves through 1 km in 100 s with uniform acceleration. What will be its speed at the end of 100 s.

Data: Initial Velocity = $v_i = 0ms^{-1}$

Distance covered = S = 1 km

$S = 1 \times 1000m = 1000m$

Time = t = 100 sec

Required: Final velocity = v_f = ?

Formula: $v_f = v_i + at$

Solution: The value of final velocity can be found out as;

$$S = v_i t + \frac{1}{2} at^2$$

By putting all values, we get.

$$1000 = (0) + \frac{1}{2} (a) (100)^2$$

$$1000 = 0 + \frac{1}{2} (a) (10000)$$

$$1000 = a (5000)$$

$$\frac{1000}{5000} = a$$

$$\boxed{a = 0.2 \text{ ms}^{-2}}$$

As we know that:

$$v_f = v_i + at$$

By putting all values, we get:

$$v_f = (0) + (0.2) (100)$$

$$v_f = 0 + 20$$

$$\boxed{v_f = 20 \text{ ms}^{-1}}$$

Answer: The required speed of the train at the end is $20ms^{-1}$.

2.3 A car has a velocity of 10 ms⁻¹. It accelerates at 0.2 ms⁻² for half minute. Find the distance travelled during this time and the final velocity of the car.

Data: Initial velocity = $v_i = 10 \text{ ms}^{-1}$

Time = t = half minutes.

Time = t = 30 sec.

Acceleration = a = $0.2ms^{-2}$

Required: Distance covered by the body = S = ?

Final velocity = v_f = ?

Formulas: $S = v_i t + \frac{1}{2} at^2$

$v_f = v_i + at$

Solution: According to the second equation of motion we know,

$$S = v_i t + \frac{1}{2} at^2$$

By Putting the all values, we get;

$$S = (10)(30) + \frac{1}{2}(0.2)(30)^2$$

$$S = 300 + \frac{1}{2}(0.2)(900)^2$$

$$S = 300 + \frac{1}{2}(180)$$

$$S = 300 + 90$$

$$\boxed{S = 390 \text{ m}}$$

The value of final velocity can be found out as;

$$v_f = v_i + at$$

$$v_f = 10 + (0.2)(30)$$

$$v_f = 10 + 6$$

$$\boxed{v_f = 16 \text{ ms}^{-1}}$$

Answers: The required distance travelled by the car is 390m.

The required final velocity of the car is 16 ms^{-1}.

2.4 A tennis ball is hit vertically upward with a velocity of 30 ms^{-1}. It takes 3 s to reach the highest point. Calculate the maximum height reached by the ball. How long it will take to return to ground?

Data: Initial velocity = $v_i = 30ms^{-1}$

Gravitational acceleration = g = $-10ms^{-2}$

Time = t = 3s

Required: Height = h = ?

Time taken by ball to come on the Earth = t = ?

Formula:

$$h = v_i t + \frac{1}{2} gt^2$$

Solution: The maximum height of the ball can be found out by following way:
The value of gravitational acceleration will be negative because it is moving upward.

$$h = (30 \text{ ms}^{-1})(3s) + \frac{1}{2}(-10)(3s)^2$$

$$h = 90 + \frac{1}{2}(-10)(9)$$

$$h = 90 - 45$$

$$\boxed{h = 45\ m}$$

The time which is taken by the ball to come on the ground.

Data can be written in this case as,

Initial velocity = v_i = $0ms^{-1}$

Gravitational acceleration = g = $10ms^{-2}$

Time = t = ?

Distance = height = h = 45m

As we know from second equation of motion:

$$h = v_i t + \frac{1}{2}at^2$$

By putting values, we get.

$$45m = (0)(t) + \frac{1}{2}(10)(t^2)$$

$$45m = 0 + 5t^2$$

$$\frac{45}{5} = t^2$$

$$t = 9$$

By taking under root on both side.

$$\sqrt{t^2} = \sqrt{9}$$

$$\boxed{t = 3s}$$

Total time taken by the ball to come on ground = Time which is taken by the ball to reach at maximum height + Time which is taken by the ball to come on ground

t = 3s + 3s

$$\boxed{t = 6s}$$

Answer: The required height reached by the ball is 45m.

The time taken by the ball to return to ground is 6s.

2.5 A car moves with uniform velocity of 40 ms⁻¹ for 5 s. It comes to rest in the next 10 s with uniform deceleration. Find (i) deceleration; (ii) total distance travelled by the car.

Data: Time = t = 10sec

Initial velocity = v_i = $40ms^{-1}$

Final velocity = v_f = $0ms^{-1}$

Required: Deceleration = ?

Total distance covered by car = ?

Formulas: $v_f = v_i + at$

$S = v \times t$

Solution: The value of final velocity can be found as.

$v_f = v_i + at$

$0 = 40 + (a)(10)$

$0 = 40 + 10a$

$-40 = 10a$

$\frac{-40}{10} = a$

$\boxed{a = -4\ ms^{-2}}$

In this case the covered distance can be derived as.

Now distance travelled in Ist 5sec.

$S_1 = v \times t = 40 \times 5 = 200m$

And for next 10 sec, the distance travelled is

$$2aS = v_f^2 - v_i^2 \qquad \because \begin{cases} v_i = 40ms^{-1} \\ v_f = 0ms^{-1} \\ a = -4ms^{-2} \end{cases}$$

$2(-4)S = 0^2 - 40^2$

$-8S_2 = -1600$

$S_2 = 200\ m$

Thus total distance covered:

$S = S_1 + S_2 = 200 + 200 = 400\ m$

2.6 A train starts from rest with an acceleration of 0.5 ms^{-2}. Find its speed in kmh^{-1}, when it has moved through 100 m.

Data: Initial Velocity $= v_i = 0\ ms^{-1}$

Acceleration $= a = 0.5\ ms^{-2}$

Distance $= S = 100m$

Required: Final velocity $= v_f = ?$

Value of velocity in kilometre per hour = ?

Formula: $2aS = v_f^2 - v_i^2$

Solution:

$2\ aS = v_f^2 - v_i^2$

$2(0.5)(100) = v_f^2 - v_i^2$

$100 = v_f^2 - (0)^2$

$\sqrt{100} = \sqrt{v_f^2}$

$v_f = 10ms^{-1}$

To convert the velocity into kilometer per hour it will be multiplied by 3600 and divided by 1000.

so; $v_f = 10ms^{-1}$

$$v_f = \frac{10 \times 3600}{1000}$$

$$v_f = \frac{36000}{1000}$$

$$\boxed{v_f = 36\ kmh^{-1}}$$

Answer: The final velocity in kilometre per hour is $36kmh^{-1}$.

2.7 A train starting from rest, accelerates uniformly and attains a velocity 48 km/h in 2 minutes. It travels at this speed for 5 minutes. Finally, it moves with uniform retardation and is stopped after 3 minutes. Find the total distance travelled by the train.

Part I

Data:

Initial velocity = v_i = $0ms^{-1}$

Time = t = 2minutes.

time = 20 × 60 = 120 seconds.

Final velocity = v_f = 48 kmh^{-1}

To convert kilometer per hour into metre per second it will be multiplied by 1000 and divided by 3600.

$$v_f = \frac{48 \times 1000}{3600}$$

$$v_f = \frac{480}{36}$$

$$\boxed{v_f = 13.333\ ms^{-1}}$$

Required: Total distance covered = S_1 = ?

Formula: $S_1 = v_{av} \times t \longrightarrow (1)$

Solution: $v_{av} = \frac{v_f + v_i}{2}$

$$v_{av} = \frac{13.333 + 0}{2}$$

vav = $6.6665\ ms^{-1}$

S_1 = 6.6665×120 seconds.

S_1 = 799.98 m

$$\boxed{S_1 = 800\ m}$$

Part II

Data: Uniform velocity = v = $13.333ms^{-1}$

Time = t = 5 minutes = 5 × 60 = 300 seconds

Required: Total covered distance = S = ?

$S_2 = v \times t$

Solution: By putting values we, get:

$S_2 = 13.333 \times 300$

$S_2 = 799.98$ metre

$\boxed{S_2 = 4000}$

Part III

Data: Initial velocity = v_i = $13.333ms^{-1}$

Final velocity = v_f = $0ms^{-1}$

Time = t = 3minutes

Time = t = $3\times60 = 180$ seconds

Required: Total covered distance = S_3 = ?

Formula: $S_3 = v_{av} \times t \longrightarrow (2)$

As we know: $v_{av} = \frac{v_f + v_i}{2}$

$v_{av} = \frac{0+13.333}{2}$

$\boxed{v_{av} = 6.6665ms^{-1}}$

By putting the value of v_{av} in equation (2); we get;

$S_3 = V_{av} \times t$

$= 6.6665\times180$

$S_3 = 1199.97\text{ m} = 1200$

Total covered distance can be found out by the addition of S_1, S_2 and S_3.

So,

Total covered distance = $S = S_1 + S_2 + S_3$

$S = 800 + 4000 + 1200$

$\boxed{S = 6000m}$

Answer: Total distance travelled by the train is 6000m.

2.8 A cricket ball is hit vertically upwards and returns to ground 6 s later. Calculate (i) maximum height reached by the ball; (ii) initial velocity of the ball.

Data: Final velocity = $v_f = 0ms^{-1}$

Gravitational acceleration = $g = -10ms^{-2}$

(Because the ball is moving in upward direction)

Time taken by the ball returns to ground = 6sec

Time taken by the ball to reach maximum height = $\frac{6}{2} = 3$ sec

Required: Maximum height = h = ?
Initial velocity = v_i = ?

Formulas: $v_f = v_i + gt$

$$2gh = v_f^2 - v_i^2$$

Solution:

By using the first equation of motion, the value of initial velocity can be found out:

$$v_f = v_i + at$$

By putting values, we get.

$$(0) = v_i + (-10)(3)$$
$$0 = v_i - 30$$
$$0+30 = v_i$$
$$\boxed{v_i = 30\text{ms}^{-1}}$$

By using the third equation of motion the value of maximum height can also be found out.

$$2gh = v_f^2 - v_i^2$$

By putting values, we get.

$$2(-10)(h) = (0) - (30)^2$$
$$-20(h) = -900$$
$$h = \frac{-900}{-20}$$
$$\boxed{h = 45\text{m}}$$

Answer:
- The required initial velocity of the ball is 30ms^{-1}.
- The required maximum height reached by the ball is 45 m.

2.9 When brakes are applied, the speed of a train decreases from 96 kmh^{-1} to 48 kmh^{-1} in 800 m. How much farther will the train move before coming to rest? (Assuming the retardation to be constant).

Data: Initial velocity $= v_i = 96\text{km/h} = \frac{96\times1000}{3600} = 26.66\text{ms}^{-1}$

Final velocity $= v_f = 48\text{km/h} = \frac{48\times1000}{3600} = 13.33\text{ms}^{-1}$

Distance covered = S = 800m

Required: Distance the train will move before coming to rest = ?

Formula: $2aS = v_f^2 - v_i^2$

Solution: First of all we will find out the value of acceleration, which can be determined by using first equation of motion.

$$v_f = v_i + at$$
$$v_f - v_i = at$$
$$\frac{v_f - v_i}{t} = a \longrightarrow (1)$$

For the calculation of (t), we use following equation.

$$S = v_{av} \times t$$
$$S = \left(\frac{v_i + v_f}{2}\right) \times t$$
$$800 = \left(\frac{26.66 + 13.33}{2}\right) t_1$$
$$800 = 19.995\, t_1$$
$$t_1 = \frac{800}{19.995} = 40.01 \text{ sec}$$

By putting the value of (t) in equation (1), we get;

$$a = \frac{v_f - v_i}{t}$$
$$a = \frac{13.33 - 26.26}{40.01} = -0.333\text{ms}^{-2}$$

Negative sign shows the velocity of the body is decreasing.

So the distance covered by the train before coming to rest can be found out as.

$$2aS = v_f^2 - v_i^2$$

By putting values, we get;

$$2(-0.333)S = -(13.33)^2$$
$$S = \frac{177.69}{2 \times 0.333}$$
$$\boxed{S = 266.80 \text{ m}}$$

Answer: The required distance will the train move before coming to rest is 266.80m.

2.10 In the above problem, find the time taken by the train to stop after the application of bakes.

Data: Initial velocity $= v_i = 96\text{kmh}^{-1}$

$$v_i = \frac{96 \times 1000}{3600} = 26.66\text{ms}^{-1}$$

Final velocity $= v_f = 0$

Acceleration $= a = -0.333 \text{ ms}^{-2}$

time $= t = ?$

By using 1st equation of motion.

$$v_f = v_i + at$$

$$t = \frac{v_f - v_i}{t}$$

By putting the values

$$t = \frac{0 - 26.66}{-0.333}$$

$$t = 80 \text{ sec}$$

Thus, the total time to stop the train is 80 sec.

OBJECTIVE TYPE QUESTIONS (MCQ'S+SHORT ANSWER) FROM PREVIOUS ANNUAL PAPERS OF ALL SECONDARY BOARDS (LAHORE, GUJRANWALA, FAISALABAD, MULTAN, SAHIWAL, SARGODHA, RAWALPINDI, D.G. KHAN And BAHAWALPUR)

2.1+2.2	Rest and motion+Types of motion
2.3	Scalars and Vectors

☆ **Tick the correct answer.**

1. **The motion of body about an axis is called:** (LHR. GI, DGK. GI, FBD. GII, SGD. GI, MLN. GI)
   (A) Circular motion (B) Rotatory motion
   (C) Vibratory motion (D) Random motion
2. **Brownian motion is an example of:** (GRW. GI, SWL. GI)
   (A) random motion (B) linear motion (C) circular motion (D) vibratory motion
3. **The to and fro motion of a body about its mean position is called:** (GRW. GI & GII)
   (A) circular motion (B) random motion (C) rotatory motion (D) vibratory motion
4. **See-Saw is an example of:** (RWP. GI)
   (A) Translatory motion (B) Linear motion
   (C) Random motion (D) Vibratory motion
5. **The motion of body in straight line is:** (LHR. GII)
   (A) Random motion (B) Circular motion
   (C) Linear motion (D) Translatory motion
6. **The motion of insects is called:** (GRW. GII)
   (A) random motion (B) circular motion (C) rotatory motion (D) vibratory motion

Answers

1. Rotatory motion 2. random motion 3. vibratory motion

4. Vibratory motion **5.** Linear motion **6.** random motion

☆ Give short answer to the following questions.

1. What is meant by Kinematics? (GRW. GII)

Ans. Kinematics is the study of motion of an object without discussing the cause of motion.

2. Define rest and motion. (GRW. GII, FBD. GI, MLN. GII, SWL. GII, DGK. GII, BWP. GI)

Ans. Rest: A body is said to be at rest, if it does not change its position with respect to its surroundings.

Trees around the bank of the road are in rest position.

Motion:

A body is said to be in motion, if it changes its position with respect to its surroundings.

A moving bus on the road is in a state of motion.

3. Differentiate between linear and random motion. (LHR. GI, FBD. GII)

Ans. Linear motion:

☆ Straight line motion of a body is known as its linear motion.

☆ Aeroplanes flying straight in air and objects falling vertically down are the examples of linear motion.

Random motion

☆ The disordered or irregular motion of an object is called random motion.

☆ The motion of dust or smoke particles in the air is the example of random motion.

4. Give difference between circular motion and rotatory motion.

Ans. Circular Motion: (SWL. GI, MLN. GI & GII, DGK. GI, RWP. GI & GII)

☆ The motion of an object in a circular path is known as circular motion.

☆ Motion of the earth around the sun and motion of the moon around the earth are examples of circular motion.

Rotatory Motion:

☆ The spinning motion of a body about its axis is called its rotatory motion.

☆ The motion of the Earth about its own axis is rotatory motion.

The motion of a bicycle wheel about its axis is also rotatory motion.

5. Define circular motion and random motion. (SGD. GII, FBD. GI)

Ans. Circular motion: The motion of an object in a circular path is known as circular motion.

Random motion:

The disordered or irregular motion of an object is called random motion.

6. Write the difference between circular and vibratory motion. (SGD. GI, GRW. GII,)

Ans. Circular Motion:

The motion of an object in a circular path is known as circular motion.

Motion of the earth around the sun and motion of the moon around the earth are examples of circular motion.

Vibratory Motion: To and fro motion of a body about its mean position is known as vibratory motion.

Up and down movement of the children in a see-saw is an example of vibratory motion.

7. Define Linear Motion and Circular Motion. (SWL. GII, MLN. GII)

Ans. Linear motion:

Straight line motion of a body is known as its linear motion.

Circular motion:

The motion of an object in a circular path is known as circular motion.

8. Differentiate between translatory motion and circular motion. (SWL. GI, BWP. GII)

Ans. Translatory motion:

Translatory motion is a type of motion in which a body moves along a line without any rotation. This line may be straight or curved.

Circular motion:

The motion of an object in a circular path is known as circular motion.

9. Define Translatory motion and give an example. (DGK. GI)

Ans. Translatory motion: Translatory motion is a type of motion in which a body moves along a line without any rotation. This line may be straight or curved.

Example:

A car moving in a straight line has translational motion.

10. Differentiate between rotatory motion and vibratory motion. (DGK. GII)

Ans. Rotatory motion:

The spinning motion of a body about its axis is called rotatory motion.

Example:

The top is shown in a given figure. The top spins about its axis passing through it and thus it possesses rotatory motion.

An axis is a line around which a body rotates.

Vibratory motion:

To and fro motion of a body about its mean position is known as vibratory motion.

Example:

Consider the motion of a baby in a swing as shown in the given figure. It moves back and forth about its mean position. The motion of the baby repeats from one

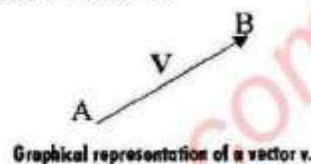
extreme to the other extreme with the swing.

11. How can vector quantities be represented graphically? (LHR. GI, RWP. GII)

Ans. Graphically a vector can be represented by a line segment with an arrow head. In the given figure the line AB with arrowhead at B represents a vector v.

The length of the line AB gives the magnitude of the vector v on a selected scale.

While the direction of the line from A to B gives the direction of the vector V.

Graphical representation of a vector v.

12. Differentiate between scalar and vector. (LHR. GII, SWL. GI, MLN. GI, SGD. GI & GII)

Ans. Scalars:

☆ A scalar is described completely by its magnitude only.

☆ Mass, length, time, speed, volume, work and energy are some examples of scalars.

Vectors:

☆ A vector is described completely by magnitude and direction.

☆ Velocity, displacement, force, momentum and torque are some examples of vectors.

13. Why vector quantities can not be added and subtracted like scalar quantities? (RWP. GI, DGK. GII)

Ans. Scalars quantities are the quantities which can be described completely by magnitude while vectors quantities need direction and magnitude for their complete description.

The quantities having direction cannot be added and subtracted like scalar quantities.

2.4+2.5 Terms associated with motion + Graphical analysis of motion

2.6+2.7 Equations of motions + Motion of freely falling objects

☆ **Tick the correct answer.**

1. A ball is thrown vertically upwards. Its velocity at the highest point is: (LHR. GI, SGD. GI & GII, MLN. GII, DGK. GII, RWP. GI)

(A) -10m/s (B) Zero (C) $10ms^{-2}$ (D) None of these

2. By dividing displacement of a moving body with time, we obtain: (LHR. GII, BWP. GI, SGD. GII, SWL. GII)

(A) Speed (B) Acceleration (C) Velocity (D) Deceleration

3. The speed of cheetah is: (GRW. GII, BWP. GII, RWP. GI)

(A) 200 kmh^{-1} (B) 70 kmh^{-1} (C) 100 kmh^{-1} (D) 90 kmh^{-1}

4 A change in position is called: (FBD. GI, DGK. GI, SWL. GII, BWP. GII, SGD. GI)

(A) Speed (B) Velocity (C) Displacement (D) Distance

5. **A train is moving at a speed of $36kmh^{-1}$. Its speed expressed in ms^{-1} is:** (FBD. GI, MLN. GI, BWP. G II, GRW. GI)
(A) $10ms^{-1}$ (B) $20ms^{-1}$ (C) $25ms^{-1}$ (D) $30ms^{-1}$

6. **A car is moving with speed of $20ms^{-1}$. Its speed in kmh^{-1} will be:** (FBD. GII, DGK. GI)
(A) $36kmh^{-1}$ (B) $50kmh^{-1}$ (C) $72kmh^{-1}$ (D) $100kmh^{-1}$

7. **________ is not a vector quantity.** (MLN. GII)
(A) Displacement (B) Velocity (C) Work (D) Torque

8. **Which of the following is a vector quantity:** (SWL. GI, RWP. GI, LHR. GI, FBD. GI)
(A) speed (B) distance (C) displacement (D) power

9. **The acceleration of a body falling down freely is approximately:** (SWL. GI, BWP. GI)
(A) $10m^2s^{-2}$ (B) $10ms^{-2}$ (C) $10ms^{-1}$ (D) $10m^2s^{-1}$

10. **Speed of Falcon is:-** (SGD. GI)
(A) $150kmh^{-1}$ (B) $250kmh^{-1}$ (C) $300kmh^{-1}$ (D) $200kmh^{-1}$

11. **A car starts from rest. It acquires a speed of $25ms^{-1}$ after 20 sec. The distance moved by the car during this time is:** (SGD. GII, RWP. GI)
(A) 31.25m (B) 250m (C) 500m (D) 5000m

12. **Which of the following is a vector quantity?** (RWP. GI)
(A) Speed (B) Distance (C) Velocity (D) Mass

13. **The distance covered in a unit time is called:** (MLN. GI)
(A) Speed (B) Velocity (C) Acceleration (D) Uniform velocity

14. **The unit of acceleration is:** (MLN. GI, SWL. GI)
(A) Nm (B) ms^{-2} (C) ms^{-1} (D) $kg\ m^{-1}$

15. **a = __________ :** (MLN. GII)
(A) $\frac{v_f - v_i}{t}$ (B) $\frac{v_f + v_i}{t}$ (C) $\frac{v_f \times v_i}{t}$ (D) $\frac{t}{v_f - v_i}$

16. **The unit of acceleration is:** (RWP. GII)
(A) kmh^{-1} (B) ms^{-1} (C) kmh^{-2} (D) kms^{-1}

17. **Which of the following is a vector quantity?** (DGK. GI)
(A) Force (B) Mass (C) Speed (D) Time

18. **Negative Acceleration is also called:** (BWP. GI)
(A) Displacement (B) Deceleration (C) Retardation (D) Both B and C

19. If an object is moving with constant speed then its distance-time graph will be a straight line: (SGD. GII, DGK. GI)

(A) Along time-axis (B) Along distance-axis
(C) Parallel to time axis (D) Inclined to time-axis

20. $V_f^2 - V_i^2 =$ __________: (FBD. GII)

(A) V_{ave} (B) S (C) 2aS (D) t

Answers

1.	Zero	**2.**	Velocity	**3.**	70 kmh^{-1}	**4.**	Distance	**5.**	$10ms^{-1}$
6.	$72kmh^{-1}$	**7.**	Work	**8.**	displacement	**9.**	$10ms^{-2}$	**10.**	$200kmh^{-1}$
11.	250m	**12.**	Velocity	**13.**	Speed	**14.**	ms^{-2}	**15.**	$\frac{v_f - v_i}{t}$
16.	kmh^{-2}	**17.**	Force	**18.**	Both B and C	**19.**	Parallel to time axis		
20.	2aS								

☆ Give short answer to the following questions.

1. Differentiate between the speed and velocity. (LHR. GI, FBD. GII, SGD. GII, DGK. GII)

Ans. Speed: ☆ The distance covered by an object in unit time is called its speed.

☆ Speed can be calculated by given formula.

$$\text{Speed} = \frac{\text{distance covered}}{\text{time}}$$

☆ Speed is a scalar quantity. Because it can be described completely by a magnitude only.

Velocity: ☆ The rate of displacement of a body is called its velocity.

☆ Velocity can be calculated by given formula.

$$\text{Velocity} = \frac{\text{displacement}}{\text{time taken}}$$

☆ Velocity is a vector quantity. Because it can be described completely by a magnitude and direction.

2. Can a body moving at a constant speed have acceleration? (LHR. GII, MLN. GII)

Ans. Yes a body moving at a constant speed have acceleration if it changes its direction or moving in a circular path.

3. Differentiate between distance and displacement.

Ans. Distance: (GRW. GI, FBD. GI, RWP. GI, DGK. GI, SWL. GII)

☆ Length of a path between two points is called the distance between those points.

☆ Distance is a scalar quantity because it can be completely described with the help of magnitude only.

Displacement:

☆ Displacement is the shortest distance, between two points which has magnitude and

direction.

☆ Displacement is a vector quantity because it can be completely described with the help of magnitude and direction.

4. Define uniform acceleration. (FBD. GI, DGK. GI, MLN. GII)

Ans. A body has uniform acceleration if it has equal changes in velocity in equal intervals of time however short the interval may be.

5. Define acceleration. (FBD. GII, LHR. GI, SGD. GI & GII, BWP. GII)

Ans. Acceleration is defined as the rate of change of velocity of a body.

Acceleration can be calculated as.

$$\text{Acceleration} = \frac{\text{Change in velocity}}{\text{time taken}}$$

Unit of acceleration is metre per second per second (ms^{-2}).

It is a vector quantity.

6. A sprinter completes its 100m race in 12 seconds. Find its average speed. (MLN. GI, RWP. GI & GII, DGK. GI)

Sol. Total distance = 100 m

Total time = 12 sec

$$\text{Average speed} = \frac{\text{Total distance}}{\text{total time}}$$

Average speed = $8.33\ ms^{-1}$

Hence average speed of sprinter is $8.33ms^{-1}$

7. Describe with example the position of a body. (SGD. GI, GRW. GI)

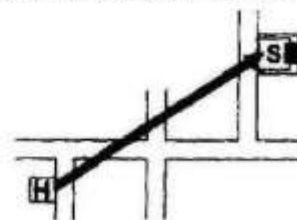
Ans. Position: Position means the location of a certain place or object from a reference point.

OR

The term position describes the location of a place or a point with respect to some reference point called origin.

Explanation: If someone wants to describe the position of his/her school from home.

Let the school be represented by S and home by H as shown in the figure.

The position of the school from home will be the distance and is represented by a straight line HS in the direction from H to S as shown in given figure.

Position of the school S from the home H.

8. Differentiate between variable and uniform speed. (SGD. GI, RWP. GI)

Ans. Variable speed: A body has variable speed if it covers equal distances in unequal intervals of time however short the interval may be.

Uniform Speed:

A body has uniform speed if it covers equal distances in equal intervals of time however short the interval may be.

(OR)

If the speed of the body does not vary and has the same value then the body is said to posses uniform speed.

9. A train is moving at a speed of 36kmh^{-1}. What will be its velocity in ms^{-1}? **(DGK. GII)**

Ans. $36\ kmh^{-1} = \frac{36 \times 1000}{3600} ms^{-1} = 10\ ms^{-1}$

10. What is meant by positive and negative acceleration? **(BWP. GII, GRW. G I)**

Ans. Positive acceleration:

Acceleration of a body is positive if its velocity increases with time.

The direction of this acceleration is the same in which the body is moving without change in its direction.

Negative Acceleration:

Acceleration of a body is negative if velocity of the body decreases.

The direction of negative acceleration is opposite to the direction in which body is moving.

11. Convert 20ms^{-1} velocity in kmh^{-1}. **(BWP. GII)**

Ans. $20\ ms^{-1} = \frac{20}{1000} \times 3600 kmh^{-1} = \frac{72000}{1000} kmh^{-1} = 72\ kmh^{-1}$

12. Define the terms velocity and acceleration. **(LHR. GII)**

Ans. Velocity:

The rate of displacement of a body is called its velocity.

Velocity can be calculated as $v = \frac{d}{t}$

Unit of velocity is metre per second (ms^{-1})

Acceleration:

Acceleration is defined as the rate of change of velocity of a body.

Acceleration can be calculated as.

$$\text{Acceleration} = \frac{\text{Change in velocity}}{\text{time taken}}$$

Unit of acceleration is metre per second per second (ms^{-2}).

13. Convert 10kmh^{-1} into ms^{-1}. **(BWP. GI)**

Ans. $10kmh^{-1} = \frac{10 \times 1000}{3600} ms^{-1} = 2.78ms^{-1}$

14. Define Speed and Uniform Speed. (BWP. G II)

Ans. Speed:

The distance covered by an object in unit time is called its speed.

Uniform Speed:

A body has uniform speed if it covers equal distances in equal intervals of time however short the interval may be.

(OR)

If the speed of the body does not vary and has the same value then the body is said to posses uniform speed.

15. Define Velocity and Uniform velocity. (SWL. GI, BWP. GII, BWP. GI & GII, GRW. GII)

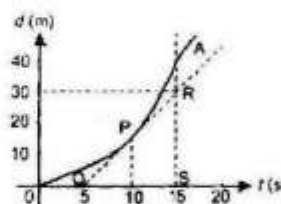
Ans. Velocity: The rate of displacement of a body is called its velocity.

Uniform velocity:

A body has uniform velocity if it covers equal displacement in equal intervals of time however short the interval may be.

If the speed and direction of a body does not change, then it posses uniform velocity.

16. What would be the shape of a speed - time graph of a moving body with variable speed? (LHR. GII)

Ans. When a body is moving with variable speed, the shape of its speed-time graph is not a straight line.

17. Write the second and third equation of motion in mathematical form. (GRW. GII, SGD. GII)

Ans. Second equation of motion: $S = v_i t + \frac{1}{2}at^2$

Third equation of motion: $2aS = v_f^2 - v_i^2$

18. Define gravitational acceleration and write its value. (GRW. GII, FBD. GI, RWP. GII)

Ans. Gravitational acceleration: The acceleration of a freely falling bodies is called gravitational acceleration. It is denoted by **g**.

Value of g: On the surface of the Earth, the value of **g** is approximately $10ms^{-2}$.

⇒ For bodies falling freely g is positive.

⇒ For bodies, moving up g is negative.

DYNAMICS

STUDENTS LEARNING OUTCOMES

After studying this unit, the students will be able to:

- define momentum, force, inertia, friction, centripetal force.
- solve problems using the equation: Force = change in momentum/change in time.
- explain the concept of force by practical examples of daily life.
- state Newton's laws of motion.
- distinguish between mass and weight and solve problems using F = ma, and w = mg.
- calculate tension and acceleration in a string during motion of bodies connected by the string and passing over frictionless pulley using second law of motion.

- state the law of conservation of momentum.
- use the principle of conservation of momentum in the collision of two objects.
- determine the velocity after collision of two objects using the law of conservation of momentum.

Conceptual Linkage	
This chapter is built on	
Force and Motion	– Science-IV
This chapter leads to:	
Motion and Force	– Physics-XI

- explain the effect of friction on the motion of a vehicle in the context of tyre surface, road conditions including skidding, braking force.
- demonstrate that rolling friction is much lesser than sliding friction.
- list various methods to reduce friction.
- explain that motion in a curved path is due to a perpendicular force on a body that changes direction of motion but not speed.
- calculate centripetal force on a body moving in a circle using mv^2/r.
- state what will happen to you while you are sitting inside a bus when the bus
  - (i) starts moving suddenly
  - (ii) stops moving suddenly
  - (iii) turns a corner to the left suddenly.
- write a story about what may happen to you when you dream that all frictions suddenly disappeared. Why did your dream turn into a nightmare?

Major Concepts:	
3.1	Momentum
3.2	Newton's laws of motion
3.3	Friction
3.4	Uniform circular motion

INVESTIGATION SKILLS:

- Identify the relationship between load and friction by sliding a trolley carrying different loads with the help of a spring balance on different surfaces.

SCIENCE, TECHNOLOGY AND SOCIETY CONNECTION:

- Identify the principle of dynamics with reference to the motion of human beings, objects, and vehicles (e.g. analyse the throwing of a ball, swimming, boating and rocket motion).
- Identify the safety devices (such as packaging of fragile objects, the action of crumple zones and seatbelts) utilized to reduce the effects of changing momentum.
- Describe advantages and disadvantages of friction in real-world situations, as well as methods used to increase or reduce friction in these situations (e.g. advantages of friction on the surface of car tyres (tyre tread), cycling, parachute, knots in string; disadvantages of friction and methods for reducing friction between moving parts of industrial machines and on wheels spinning on axles).
- Identify the use of centripetal force in **(i)** safe driving by banking roads **(ii)** washing machine dryer **(iii)** cream separator.

In kinematics, we have studied the changes in motion only. Our understanding about the changes in motion is of little value without knowing its causes. The branch of mechanics that deals with the study of motion of an object and the cause of its motion is called dynamics. In this unit, we shall study momentum and investigate what causes a change in the motion of a body and what role the mass of a body plays in its motion. This inquiry leads us to the concept of force. We shall also study the laws of motion and their applications.

3.1 Force, Inertia and Momentum

Q.1. What is dynamics? What do you know about force, inertia and momentum? Explain your answer with suitable examples.

Ans: Dynamics: The branch of mechanics that deals with the study of motion of an object and the cause of its motion is called dynamics.

Force: The agency which moves or tends to move, stops or tends to stop the motion of a body is called force.

⇒ The force can also change the direction of motion of a body.

Example # 1: The force can also change the shape or size of a body on which it acts.

A door can be opened or closed by applying a force in the form of pushing and pulling.

Example # 2: A man is pushing a cart in the given figure. The push may move the cart or change the direction of its motion or may stop the moving cart.

Figure 3.1: The food vendor on move

Example # 3:

In the given figure (3.2) a batsman is changing the direction of a moving ball by

pushing it with his bat.

Example # 4: A force may not always cause a body to move.

In a given figure (3.3) a boy is pushing a wall and is thus trying to move it but it does not move.

Example # 5:

In a given figure (3.4) a goalkeeper needs a force to stop a ball coming to him.

Figure 3.2: Ball is turned into different direction as it is pushed by the batsman

Figure 3.3: A boy is pushing the wall

Figure 3.4: Goalkeeper is stopping the ball

Example#6:

An apple can be cut with a knife by pushing its sharp edge into the apple.

Inertia: Inertia of a body is its property due to which it resists any change in its state of rest or motion.

Inertia depends upon mass: Intertia of the body depends on its mass, greater is the mass of a body, greater is its inertia.

Galileo's observation: Galileo observed that it is easy to move or to stop light objects than heavier ones. Heavier objects are difficult to move or if moving then difficult to stop. Heavier bodies have high inertia and lighter bodies have low inertia.

Figure 3.5: The coin falls into the glass as the card flicks away

Example # 1: Take a glass and cover it with a piece of cardboard. Place a coin on the cardboard as shown in given figure. Now flick the card horizontally with a jerk of finger. The coin falls into the glass due to inertia while the card flicks away.

Example # 2: Cut a strip from a sheet of paper as shown in figure. Place it on a table. Stack a few coins at its one end as shown in the figure. It will be noticed that on pulling the paper quickly under the coins prevents the coins to topple due to inertia.

Figure 3.6: Coins stacked over remain undisturbed on pulling the paper strip quickly

Momentum: Momentum of a body is the quantity of motion it possesses due to its mass and velocity.

Formula: The momentum P of a body is given by the product of its mass (m) and its velocity (v).

$$P = mv$$

Unit: The unit of momentum in system international is kg ms^{-1}

Vector quantity: Momentum is a vector quantity because it needs magnitude, unit and specific direction for its complete description

Example #1: The impact of a loaded truck on a body coming its way is very large even if the truck is moving slowly. Because a great mass has great momentum.

Example #2: A bullet has a very small inertia due to its small mass. But when it is fired from the gun its impact is very strong because it is fired with greater velocity.

3.2 Newton's Laws of Motion

Q.2. State Newton's first law of motion. Explain this law with examples. Why first law of motion is also called law of inertia?

Ans: Newton's First Law of Motion: A body continues its state of rest or of uniform motion in a straight line unless acted upon by a net force.

Explanation: First law of motion deals with bodies which are either at rest or moving with uniform speed in a straight line. This law has two part.

Net force is the resultant of all the forces acting on a body.

Explanation of 1st part with example:

The first part of the 1st law is concerned with the bodies at rest. According to 1st law of motion a body at rest remains at rest provided no net force acts on it.

Example: A book lying on a table remains at rest as long as no net force acts on it.

Conclusion: This part of the law is true as we observe that objects do not move by themselves unless someone moves them.

Explanation of 2nd part with example:

Second part of the Newton's first law of motion deals with bodies in motion.

Example: A moving object does not stop moving by itself. A ball rolled on a rough ground stops earlier than that rolled on a smooth ground. It is because rough surfaces offer greater friction. If there would be no force to oppose the motion of a body then the moving body would never stop.

DO YOU KNOW?

When a bus takes a sharp turn, passengers fall in the outward direction. It is due to inertia that they want to continue their motion in a straight line and thus fall outwards.

First law of motion is the law of inertia:

Newton's first law of motion deals with the inertial property of matter, therefore, Newton's first law of motion is also known as law of inertia.

Example:

The passengers standing in a bus fall forward when its driver applies brakes suddenly. It is because the upper parts of their bodies tend to continue their motion, while

lower parts of their bodies in contact with the bus stop with it. Hence they fall forward.

Q.3. State Newton's second law of motion. Prove its mathematical formula. Also derive the unit of force.

Ans: Newton's second law of motion deals with situations when a net force is acting on a body.

Statement: When a net force acts on a body, it produces acceleration in the body in the direction of the net force. The magnitude of this acceleration is directly proportional to the net force acting on the body and inversely proportional to its mass.

Mathematical formula: If a force produces an acceleration a in a body of mass m then it can be stated mathematically that

$$a \propto F \quad \text{____ (i)}$$

$$a \propto \frac{1}{m} \quad \text{____ (ii)}$$

By combining eq (i) and (ii)

$$a \propto \frac{F}{m}$$

$$F \propto ma$$

Putting k as proportionality constant,

$$F = k\,m\,a \quad \text{____ (iii)}$$

In SI units, the value of k comes out to be 1. Thus eq. (iii) becomes.

$$F = ma$$

Unit: SI unit of force is newton (N).

Definition of newton: One newton (1N) is the force that produces an acceleration of 1 ms^{-2} in a body of mass of 1kg.

Derivation of unit newton:

Using Newton's second law of motion, a force of one newton can be expressed as

$$1\text{ N} = 1\text{kg} \times 1\text{ ms}^{-2}$$

$$1\text{N} = 1\text{kg ms}^{-2}$$

Example 3.1

Find the acceleration that is produced by a 20 N force in a mass of 8 kg.

Solution: Here $m = 8\text{kg}$

$F = 20\text{ N}$

$a = ?$

using the formula $F = ma$

$$20\text{ N} = 8\text{ kg} \times a$$

or $$a = \frac{20\text{N}}{8\text{kg}}$$

or $$a = 2.5\frac{\text{kg ms}^{-2}}{\text{kg}}$$

$a = 2.5\ ms^{-2}$

Thus acceleration produced by the force is $2.5\ ms^{-2}$.

Example 3.2 ***A force acting on a body of mass 5kg produces an acceleration of $10\ ms^{-2}$. What acceleration the same force will produce in a body of mass 8kg?***

Solution: Here

$m_1 = 5kg$

$m_2 = 8kg$

$a_1 = 10\ ms^{-2}$

$a_2 = ?$

Applying Newton's second law of motion, we get;

$F = m_1 a_1$

$F = m_2 a_2$

Comparing the equations, we get;

$m_1 a_1 = m_2 a_2$

$(5kg)(10m/s^2) = (8kg)\ a_2$

or $a_2 = 6.25\ ms^{-2}$

Hence, the acceleration produced is $6.25\ ms^{-2}$.

Example 3.3 ***A cyclist of mass 40kg exerts 200 N force to move his bicycle with an acceleration of $3ms^{-1}$. How much is the force of friction between the road and the tyres.***

Solution: Here

$m = 40kg$

$a = 3\ ms^{-2}$

$F_0 = 200\ N$

Net Force $= F = ?$

Force of friction $= f = ?$

As net Force $F = m\ a$

$= 40\ kg \times 3\ ms^{-2}$

$= 120\ N$

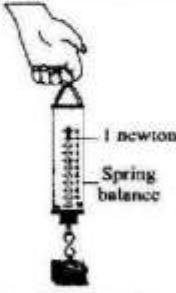
$\therefore$ Net force = Applied Force – Force of friction

$120\ N = 200 - f$

$\therefore\ f = 80\ N$

Thus, the force of friction between road and the tyres is 80 N.

Q.4. Differentiate between mass and weight:

Ans:

S.No.	Mass	Weight
1.	Mass of a body is the quantity of matter that it possesses.	1. Weight of a body is due to the force of gravity acted on it. Weight of a body is equal to the force with which Earth attracts it.
2.	Mass is a scalar quantity because it needs only magnitude, and unit for its description.	2. Weight is a vector quantity because it needs only magnitude, unit and direction for its description.
3.	Mass does not change with change of place.	3. On the Earth, weight varies depending upon the value of g acceleration due to gravity.
4.	Mass is measured by comparison with standard masses using a beam balance.	4. Weight is measured by a spring balance.
5.	Mass of a body can be derived by following equations $\frac{w}{g} = m,\ m = dV$	5. Weight of a body can be derived by following equation; $w = mg$
6.	Unit of mass is kilogram (kg)	6. Unit of weight is newton (N).
	Figure: A beam balance	1 newton; Spring balance. Figure 3.7: Spring balance is used to measure the force or weight of a body.

Q.5. State the Newton's third law of motion. Explain this law with suitable examples.

Ans: Newton's third law of motion deals with the reaction of a body when a force acts on it.

Statement: To every action there is always an equal but opposite reaction.

Explanation: Let a body A exerts a force on another body B, the body B reacts against this force and exerts a force on body A. The force exerted by body A on B is the **action force** whereas the force exerted by body on A is called the **reactional force.** According to this law, action is always accompanied by a reaction force and the two forces must

always be equal and opposite.

Action and reaction forces always act on different bodies.

Example #1: Consider a book lying on a table as shown in figure (3.8). The weight of the body is acting on the table in the downward direction. This is the action. The reaction of the table acts on the book in the upward direction.

Figure 3.8: Action of the book and reaction on it

Example #2: Take an air-filled balloon as shown in the given figure (3.9). When the balloon is set free, the air inside it rushes out and the balloon moves forward.

Action in this example: In this example, the action is by the balloon that pushes the air out of it when set free.

Reaction in this example: The reaction of the air which escapes out from the balloon acts on the balloon. Due to this reaction balloon moves forward.

Figure 3.9: Reaction of the air pushed out of the balloon moves it

Example #3:

A rocket such as shown in given figure (3.10) moves on the same principle When its fuel burns, hot gases escape out from its tail with a very high speed. The reaction of these gases on the rocket causes it to move opposite to the gases rushing out of its tail.

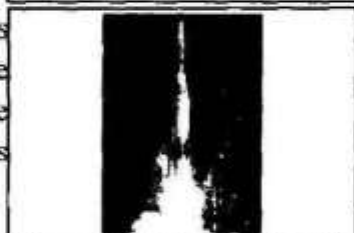



Figure 3.10: A Rocket taking off

Quick Quiz:

Stretch out your palm and hold a book on it.

1. ***How much force you need to prevent the book from falling?***

Ans: The force which is needed to prevent the book from falling is equal to the weight of the book.

2. ***Which is action?***

Ans: The weight of the book is acting in a downward direction. It is the actional force.

3. ***Is there any reaction? If yes, then what is its direction.***

Ans: Yes, there is a reaction force in this case. The force applied to prevent the book from falling is called the reactional force. The reactional force is acting in the upward direction.

Q.6. What do you understand about the tension of a string. Give explanation of your answer.

Ans: Tension of a string can be understood by the given explanation.

Explanation: Consider a block supported by a string. The upper end of the string is fixed on a stand as shown in figure.

Let w be the weight of the block. The block pulls the string downwards. This causes a tension T in the string, since its other end is fixed on the stand. The tension T in

the string is acting upwards at the block.

As the block is at rest, therefore, the weight of the block acting downwards must be balanced by the upwards tension T in the string.

Thus the tension T in the string must be equal and opposite to the weight w of the block.

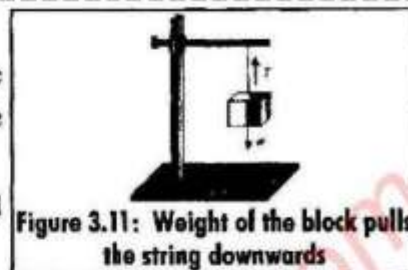



Figure 3.11: Weight of the block pulls the string downwards

Q.7. How will you find out the acceleration and tension of two bodies connected by a string that passes over a frictionless pulley when both are moving vertically?

Ans: Consider two bodies A and B of unequal masses, m_1 and m_2 respectively. The two bodies are attached to the opposite ends of an inextensible string. The string passes over a frictionless pulley as shown in figure.

Movement of body A: As m_1 is greater than m_2, therefore body A moves downwards with some acceleration. Let this acceleration be **a.**

Movement of body B: In this case, the body B attached to the other end of the string moves with the same acceleration (a) in the upward direction.

Tension in string: As the pulley is frictionless, hence tension will be the same throughout the string. Let the tension in the string be T.

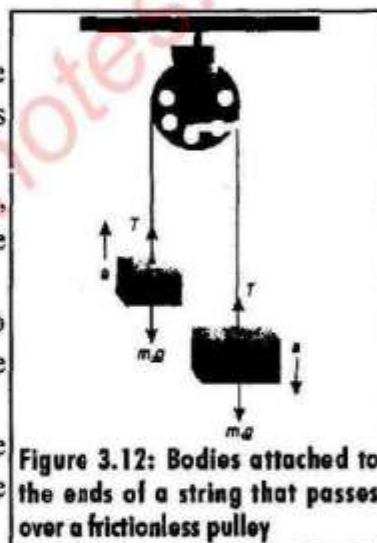



Figure 3.12: Bodies attached to the ends of a string that passes over a frictionless pulley

Forces acting on body A: There are two forces which are acting on the body A.

(i) Force of tension (T) in upward direction

(ii) Force of weight (w) in downward direction

As body A is moving downwards, therefore its weight m_1g is greater than the tension T in the string ($w > T$).

Net force on body A: Net force on body A = $m_1 g - T$

According to Newton's second law of motion.

$$F = ma$$

So; $m_1 g - T = m_1 a$ ________ (i)

Forces acting on body B:

There are two forces which are acting on body B.

(i) Force of tension (T) in upward direction.

(ii) Force of weight (w) in downward direction.

As body B is moving upwards, hence its tension T in the string is greater than its weight (w) ($T > w$).

Net force on body B:

Net force on body B = $T - m_2g$

According to Newton's second law of motion.

$$F = ma$$

$$T - m_2g = m_2a \qquad ______ (ii)$$

Value of acceleration:

Value of acceleration in this case can be found out by adding eq. (i) and (ii).

$$(T - m_2g) + (m_1g - T) = m_1a + m_2a$$

$$\cancel{T} - m_2g + m_1g - \cancel{T} = m_1a + m_2a$$

$$m_1g - m_2g = m_1a + m_2a$$

$$g(m_1 - m_2) = a(m_1 + m_2)$$

$$\frac{g(m_1 - m_2)}{m_1 + m_2} = a$$

So $$a = \frac{m_1 - m_2}{m_1 + m_2}g$$

Value of Tension:

Value of tension in this case can be found out by dividing eq. (ii) by eq. (i)

$$\frac{T - m_2g}{m_1g - T} = \frac{m_2\cancel{a}}{m_1\cancel{a}}$$

$$m_1(T - m_2g) = m_2(m_1g - T)$$

$$m_1T - m_1m_2g = m_2m_1g - m_2T$$

$$m_1T + m_2T = m_2m_1g + m_1m_2g$$

$$T(m_1 + m_2) = 2m_1m_2g$$

$$T = \frac{2m_1m_2g}{m_1 + m_2}$$

> **DO YOU KNOW?**
> An Atwood machine is an arrangement of two objects of unequal masses. Both the objects are attached to the ends of a string. The string passes over a frictionless pulley. This arrangement is sometime used to find the acceleration due to gravity.

Atwood machine:

The above arrangement given in this case is also known as Atwood machine. It can be used to find the acceleration **g** due to gravity by using following equation.

$$g = \frac{m_1 + m_2}{m_1 - m_2}a$$

Example 3.4 ***Two masses 5.2 kg and 4.8 kg are attached to the ends of an inextensible string which passes over a frictionless pulley. Find the acceleration in the system and the tension in the string when both the***

masses are moving vertically.

Solution: $m_1 = 5.2\ kg$

$m_2 = 4.8\ kg$

as $a = \frac{m_1 - m_2}{m_1 + m_2} g$

$= \frac{5.2kg - 4.8kg}{5.2kg + 4.8kg} \times 10\ ms^{-2}$

$\therefore\ a = 0.4\ ms^{-2}$

as $T = \frac{2m_1m_2}{m_1 + m_2} g$

$= \frac{2 \times 5.2kg \times 4.8kg}{5.2kg + 4.8kg} \times 10\ ms^{-2}$

$\therefore\ T = 50N$

Thus the acceleration in the system is $0.4\ ms^{-2}$ and tension in the string is 50N

Q.8. Discuss the motion of bodies connected by a string that passes over a frictionless pulley when one body moves vertically downwards while the second body moves on a smooth horizontal surface. Find out the value of tension and acceleration in this case.

Ans: Consider two bodies A and B of masses m_1 and m_2 respectively attached to the ends of an inextensible string as shown in the given figure.

Figure 3.13: Motion of masses attached to a string that passes over a frictionless pulley.

Movement of body A and body B: Let the body A moves downwards with an acceleration a since the string is inextensible, therefore, body B also moves over the horizontal surface with the same acceleration.

Tension in string: As the pulley is frictionless, hence tension T will be the same throughout the string.

Forces acting on body A: There are two forces which are acting on body A.

(i) Force of tension in upward direction

(ii) Force of weight (w) in downward direction.

As body A is moving downwards, therefore, its weight $m_1 g$ is greater than the tension T in the string. (w > T).

Net force on body A: Net force acting on body A = $m_1 g - T$

According to Newton's second law of motion.

$$F = ma$$

So, $m_1 g - T = m_1 a$ ________ (1)

Forces acting on body B: There are three forces which are acting on body B.

(i) Weight m_2g of the body acting downward.

(ii) Reaction R of the horizontal surface acting upward on the body B.

(iii) Tension T in the string pulling body B horizontally over the smooth surface.

As body B has no vertical motion, hence resultant of vertical forces (m_2g and R) must be zero.

Net force on body B: Net force acting on body B = T

According to newton's second law of motion.

$$F = ma$$

So, $T = m_2a$ ________ (2)

Value of acceleration:

Value of acceleration in this case can be found out by adding eq (1) and eq (2).

$$m_1g - \cancel{T} + \cancel{T} = m_1a + m_2a$$

$$m_1g = a(m_1 + m_2)$$

$$\frac{m_1g}{m_1 + m_2} = a$$

So $$a = \frac{m_1}{m_1 + m_2}g$$

Value of tension:

Value of tension in this case can be found out by putting the value of **a** in eq. (2)

$$T = m_2\frac{(m_1g)}{m_1 + m_2}$$

$$T = \frac{m_1m_2g}{m_1 + m_2}$$

Example 3.5 ***Two masses 4kg and 6kg are attached to the ends of an inextensible string which passes over a frictionless pulley such that mass 6kg is moving over a frictionless horizontal surface and the mass 4kg is moving vertically downwards. Find the acceleration in the system and the tension in the string.***

Solution: $m_1 = 4$ kg

$m_2 = 6$ kg

as $$a = \frac{m_1}{m_1 + m_2}g$$

$$= \frac{4\,kg}{4\,kg + 6\,kg} \times 10\,ms^{-2}$$

$$a = 4\ ms^{-2}$$

as $\therefore$ $$T = \frac{m_1 m_2}{m_1 + m_2} g$$

$$= \frac{4\,kg \times 6\,kg}{4\,kg + 6\,kg} \times 10\,ms^{-2}$$

$$\therefore \quad T = 24\ N$$

Thus the acceleration in the system is $4\,ms^{-2}$ and tension in the string is 24N.

Q.9. Explain the relation of force and momentum. Prove this relation mathematically.

Ans: Force acting on a body will be equal to the rate of change of momentum of the body.

Explanation:

Consider a body of man (m) moving with initial velocity (v_i).

Let a force acts on the body which produces an acceleration (a) in it. This changes the velocity of the body.

Let its final velocity after time (t) becomes (v_f).

P_i = Initial momentum of the body.

P_f = Final momentum of the body.

Momentum and velocities of the body can be related as

$$P_i = m\,v_i$$

$$P_f = m\,v_f$$

Change in momentum: Change in momentum can be given by this equation.

$$\Delta P = P_f - P_i$$

Change in momentum = final momentum – initial momentum

$$P_f - P_i = m\,v_f - m\,v_i$$

Rate of change in momentum:

The rate of change in momentum is given by following way:

$$\frac{P_f - P_i}{t} = \frac{mv_f - mv_i}{t}$$

$$\frac{P_f - P_i}{t} = \frac{m(v_f - v_i)}{t} \quad ______ (1)$$

As we know $\left(\frac{v_f - v_i}{t}\right) = a$, by putting the value of $\frac{v_f - v_i}{t}$ in eq.(1)

$$\frac{P_f - P_i}{t} = ma \quad _________ (2)$$

According ot the Newton's second law of motion

$$F = ma$$

So equation (2) becomes

$$\frac{P_f - P_i}{t} = F \quad ______ (3)$$

Rate of change in momentum = F.

Eq. (3) defines force and states Newton's second law of motion as.

"When a force acts on a body, it produces an acceleration in the body and will be equal to the rate of change of momentum by the body".

SI unit of momentum:

SI unit of momentum defined by eq (3) is newton – second (Ns) which is the same as kg ms^{-1}

USEFUL INFORMATION

Fragile objects such as glass wares etc. are packed with suitable materials such as styrofoam rings, balls, polythene sheets with air sacks etc.

Air enclosed in the cavities of these materials makes them flexible and soft. During any mishap, they increase the impact time on fragile objects. An increase in impact time lowers the rate of change of momentum and hence lessens the impact of force. This lowers the possible damage due to an accident.

Example 3.6

A body of mass 5 kg is moving with a velocity of 10 ms^{-1}. Find the force required to stop it in 2 seconds.

Solution:

$m = 5\ kg$

$v_i = 10\ ms^{-1}$

$v_f = 0\ ms^{-1}$

$t = 2\ s$

$F = ?$

$P_i = 5\ kg \times 10\ ms^{-1} = 50\ Ns$

$P_f = 5\ kg \times 0\ ms^{-1} = 0\ Ns$

Since $F = \frac{P_f - P_i}{t}$

$$= \frac{50Ns - 0Ns}{2s}$$

$F = 25N$

Thus 25 N force is required to stop the body.

USEFUL INFORMATION

In an accident at high speed, the impact force is very large due to the extremely short stopping time. For safety purposes, vehicles have rigid cages for passengers with crumple zones at their front and rear ends.

During an accident, crumple zones collapse. This increases the impact time by providing extra time for crumpling. The impact of force is highly reduced and saves the passengers from severe injuries.

Q.10. Define and explain the law of conservation of momentum.

Ans: Momentum of a system depends on its mass and velocity. Law of conservation of

momentum can be defined as

"The momentum of an isolated system of two or more than two interacting bodies remain constant".

USEFUL INFORMATION

In case of an accident, a person not wearing seatbelt will continue moving until stopped suddenly by something before him. This something may be a windscreen, another passenger or back of the seat in front of him/her. Seatbelts are useful in two ways:

- **They provide an external force to a person wearing seatbelt.**
- **The additional time is required for stretching seat belts. This prolongs the stopping time for momentum to change and reduces the effect of collision.**

Explanation:

Consider an isolated system of two spheres of masses m_1 and m_2 as shown in figure.

The masses m_1 and m_2 are moving in a straight line with initial velocities u_1 and u_2 respectively, such that u_1 is greater than u_2.

Sphere of mass m_1 approaches the sphere of mass m_2 as they move.

Figure 3.14: Collision of two bodies of spherical spheres

Total momentum of the system before collision:

Initial momentum of mass $m_1 = m_1 u_1$

Initial momentum of mass $m_2 = m_2 u_2$

Total initial momentum of the system before collision

$$= m_1 u_1 + m_2 u_2$$

Collision of masses: After sometime mass m_1 hits m_2 with some force.

According to Newton's third law of motion, m_2 exerts an equal and opposite force on m_1. Let their velocities become v_1 and v_2 respectively after collision.

Total momentum of the system after collision:

Final momentum of the mass $m_1 = m_1 v_1$

Final momentum of the mass $m_2 = m_2 v_2$

Total final momentum of the system after collision $= m_1 v_1 + m_2 v_2$

Law of conservation of momentum:

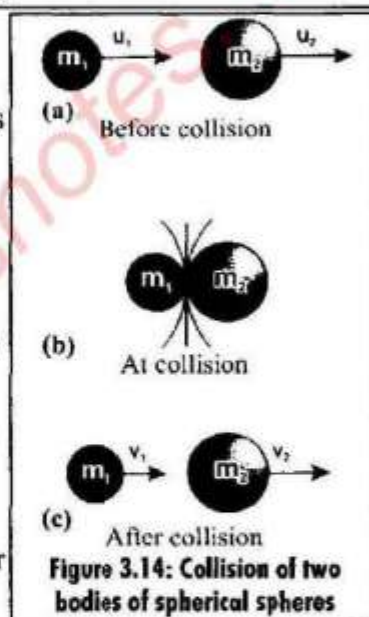
According to the law of conservation of momentum.

$$\begin{pmatrix}\text{Total initial momentum of} \\ \text{the system before collision}\end{pmatrix} = \begin{pmatrix}\text{Total final momentum of} \\ \text{the system after collision}\end{pmatrix}$$

$$m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2$$

This equation shows that the momentum of an isolated system before and after collisions remains the same which is the law of conservation of momentum.

Importance:

Law of conservation of momentum is an important law and has vast applications.

System: A system is a group of bodies within a certain boundaries.

Isolated system: An isolated system is a group of two or more interacting bodies on which no external force is acting.

If no unbalanced or net force acts on a system, then its momentum remains constant. Thus the momentum of an isolated system is always conserved. This is the Law of Conservation of Momentum.

Q.11. How following examples follow the law of conservation of momentum? Explain.

(i) A released air-filled balloon. (ii) A system of gun and a bullet.

(iii) Working of rockets and jet engine.

Ans: (i) A released air-filled balloon:

An example of an air-filled ballon can be explained under the third law of motion and the law of conservation of momentum.

In this case, balloon and the air inside it form a system.

Initial momentum of the system: Before releasing the balloon, the system was at rest and hence the initial momentum of the system was zero.

Final momentum of the system: As soon as the balloon is set free, air escapes out of it with some velocity. The air coming out of it possesses momentum.

The balloon moves in a direction opposite to that of air rushing out to conserve momentum.

(ii) A system of gun and a bullet: Consider a system of gun and bullet.

Total momentum before firing: Before firing the gun, both the gun and bullet are at rest, so the total momentum of the system is zero.

$$\begin{pmatrix}\text{Total momentum of the gun and}\\ \text{the bullet before the gun is fired}\end{pmatrix} = \text{zero}$$

Total momentum after firing:

As the gun is fired, bullet shoots out of the gun and acquires momentum.

To conserve momentum of the system, the gun recoils.

Let m be the mass of the bullet and v be its velocity on firing the gun; M be the mass of the gun and V be the velocity with which it recoils.

Thus the total momentum of the gun and the bullet after the gun is fired will be

$$\begin{pmatrix}\text{Total momentum of the gun and}\\ \text{the bullet after the gun is fired}\end{pmatrix} = MV + mv.$$

Total momentum of the system before and after firing:

According to law of conservation of momentum, the total momentum of the gun and the bullet will be zero after the gun is fired.

According to the law of conservation of momentum.

$$\begin{pmatrix}\text{Total momentum of the gun and} \\ \text{the bullet after the gun is fired}\end{pmatrix} = \begin{pmatrix}\text{Total momentum of the gun and} \\ \text{the bullet before the gun is fired}\end{pmatrix}$$

$$MV + mv = 0$$

$$MV = -mv$$

$$V = \frac{-m}{M}v$$

This equation gives the velocity V of the gun.

Meaning of negative sign:

Negative sign indicates velocity of the gun is opposite to the velocity of the bullet. i.e. the gun recoils.

As the mass of the gun is much larger than mass of the bullet, so the recoil is much smaller than the velocity of the bullet.

(iii) Working of rockets and jet engine:

Working of rockets and jet engines can be explained by law of conservation of momentum.

In these machines, hot gases produced by burning of fuel rush out with large momentum.

Rockets and jet engines gain an equal and opposite momentum. This enables them to move with very high velocities.

Example 3.7 ***A bullet of mass 20g is fired from a gun with a muzzle velocity $100ms^{-1}$. Find the recoil of the gun if its mass is 5 kg.***

Solution: $m = 20\ g = 0.02\ kg$

$v = 100\ ms^{-1}$

$M = 5\ kg$

$V = ?$

According to the law of conservation of momentum:

$$MV + mv = 0$$

Putting the values, we get

$$\therefore 5\ kg \times V + (0.02\ kg) \times (100ms^{-1}) = 0$$

or $$5\ kg \times V = -(0.02\ kg) \times (100ms^{-1})$$

or $$V = -\frac{(0.02\ kg) \times (100ms^{-1})}{5kg}$$

$$V = -0.4ms^{-1}$$

The negative sign indicates that the gun recoils i.e., moves in the backward direction opposite to the motion of the bullet with a velocity of $0.4\ ms^{-1}$.

3.3 FRICTION

Q.12. What is the force of friction and on which factors it depends? Why friction opposes motion?

Ans: Naturally there must be some force that stops moving objects. Since a force not only moves an object but also stops moving object.

Definition of friction: The force that opposes the motion of an object is called friction.

Reason of friction: Friction is a force that comes into action as soon as a body is pushed or pulled over a surface.

Friction in solids:

In case of solids, the force of friction between two bodies depends upon many factors such as nature of the two surfaces in contact and the pressing force between them.

Explanation: On rubbing palm over different surfaces such as table, carpet, polished marble surface, brick etc. it will be noticed that it is easier to move palm over a smoother surface while it is difficult to move palm over a tough or rough surface.

Friction opposes motion: In the universe all the surfaces are not perfectly smooth.

A smooth surface has pits and bumps that can be seen under a microscope.

Above figure shows two wooden blocks with their polished surfaces in contact.

Magnified view of smooth surfaces:

A magnified view of two surfaces in contact shows the gaps and contacts between them.

Figure 3.17: A magnified view of the two surfaces in contact

Magnified view of smooth surfaces:

A magnified view of two surfaces in contact, shows the gaps and contacts between them.

The contact points between the two surfaces form a sort of **cold welds.**

These cold welds resist the surfaces from sliding over each other.

Relation of pressing force and friction: From the above figure it can be easily understood. Adding weight over the upper block increases the force pressing the surfaces together and hence, increases the resistance. Thus, greater is the pressing force greater will be the friction between the sliding surfaces.

Relation of applied force and friction: Friction is equal to the applied force that tends to move a body at rest. It increases with the applied force.

Tidbits

Pushing the opposite walls by palms and feet increases friction. This enables the boy to move up on the walls.

Examples: 1. A cyclist keeps on pedalling to overcome friction.
2. To walk or to run, friction is needed to push the ground backward.

Figure 3.15: A cyclist keeps on pedalling to overcome friction.

Figure 3.16: To walk or to run friction is needed to push the ground backward.

Q.13. What is the force of limiting friction (Fs), on which factor it depends and what is coefficient of friction? Write formulas of both. Write advantages of friction.

Ans: Force of limiting friction:

Friction has a maximum value. It does not increase beyond this. The maximum value of friction is known as the force of limiting friction (F_S).

Factor on which (F_S) depends: Force of limiting friction (F_S) depends on the normal reaction (pressing force) between the two surfaces in contact.

Formula: $F_S = \mu R$

Co-efficient of friction:

The ratio between the force of limiting friction F_S and normal reaction R is constant. This constant is called the co-efficient of friction and is represented by μ.

Formula: $\mu = \frac{F_s}{R}$

If m be the mass of the block, then for horizontal surface

$$R = mg$$
$$F_S = \mu\, mg$$
$$\frac{F_s}{mg} = \mu$$

Coefficient of friction between some common materials

Materials	μ_s	Materials	μ_s
Glass and Glass	0.9	Tyre and Road, dry	1
Glass and Metal	0.5 - 0.7	Tyre and Road, wet	0.2
Ice and Wood	0.05	Wood and Wood	0.25 - 0.6
Iron and Iron	1.0	Wood and Metal	0.2 - 0.6
Rubber and Concrete	0.6	Wood and Concrete	0.62
Steel and Steel	0.8		

Advantages of friction:

1. Friction is needed to walk on the ground. It is risky to run on wet floor with shoes that have smooth soles.
2. Athletes use special shoes that have extraordinary ground grip. Such shoes provide more friction and prevent them from slipping while running fast.
3. To stop the moving bicycle, brakes will be applied. The rubber pads pressed against the rims provide friction. It is the friction that stops the bicycle.

Quick Quiz:

1. *Which shoe offer less friction?*

Ans: The smooth surface shoe offer less friction.

2. *Which shoe is better for walking on dry track?*

Ans: The smooth surface shoe is better for walking on dry track.

3. *Which shoe is better for jogging?*

Ans: The rough surface shoe is better for jogging.

4. *Which sole will wear out early?*

Ans: The smooth surface sole will wear out early.

Q.14. What is rolling friction? How it can be explained with examples?

Ans: **Rolling friction:** Rolling friction is the force of friction between a rolling body and a surface over which it rolls.

Rolling friction is much smaller than the sliding friction.

Motion of a wheel: Wheel is one of the most important inventions in the history of mankind. The first thing about a wheel is that it rolls rather than to slide as it moves. This greatly reduces friction.

Explanation of rolling friction in wheel: When the axle of a wheel is pushed, the force of friction between the wheel and the ground at the point of contact provides the reaction force. The reaction force acts at the contact points of the wheel in a direction opposite to the applied force. The wheel rolls without rupturing the cold welds. That is why, the rolling friction is extremely small than sliding friction.

Friction in ball bearings or roller: The idea that rolling friction is less than sliding friction is applied in case of ball bearings or roller bearings to reduce losses due to friction.

Figure 3.18: Friction may cause the body to roll

Figure 3.19: A ball bearing

Advantage of friction:

The wheel would not roll on pushing it if there would be no friction between the wheel and the ground. Thus, friction is desirable for wheels to roll over a surface.

It is dangerous to drive on a wet road due to small friction between the road and tyres. This increases the chance of slipping the tyres from the road.

Threading on tyres: The threading on tyres is designed to increase friction. Thus, threading improves road grip and make it safer to drive even on wet road.

Figure 3.20: Threading on tyres provides good road grip.

Application of brakes to stop bicyle: A cyclist applies brakes to stop his/her bicycle. As soon as brakes are applied, the wheels stop rolling and begin to slide over the road. Since sliding friction is much greater than rolling friction. Therefore, the cycle stops in a few moments.

Quick Quiz:

1. *Why is it easy to roll a cylindrical eraser on a paper sheet than to slide it?*

Ans: Clyindrical eraser is a rolling body and can easily rolled on a paper sheet than to slide it. Because a rolling friction is the force of friction between a rolling body and a surface over which it rolles.

2. *Do we roll or slide the eraser to remove the pencil work from our note books?*

Ans: We slide the eraser to remove the pencil work from our note book.

Q.15. What do you know about braking and skidding? Write a note.

Ans: Velocity components of wheels of a moving vehicle:

The wheels of a moving vehicle have two velocity components.

(i) Motion of wheels along the road.
(ii) Rotation of wheels about their axis.

Importance of friction:

To move a vehicle on the road as well as to stop a moving vehicle requires friction between its tyres and the road.

Explanation:

If the road is slippery or the tyres are worn out then the tyres instead of rolling, slip over the road. If the wheels start slipping at the same point on the slippery road, the vehicle will not move. Thus for the wheels to roll, the force of friction (gripping force) between the tyres and the road must be enough that prevents them from slipping.

Skidding of car: To stop a car quickly, a large force of friction between the tyres and the roads is needed. But there is a limit to this force of friction that tyres can provide. If the brakes are applied too strongly, the wheels of the car will lock up (stop turning) and the car will skid due to its large momentum. It will lose its directional control that may result in an accident.

Figure 3.21: A car skidding

Method to reduce skidding: In order to reduce the chance of skidding, it is advisable not to apply brakes too hard that lock up their rolling motion especially at high speeds. Moreover, it is unsafe to drive a vehicle with worn out tyres.

Mini Exercise:

1. *In which case do you need smaller force and why?*
   (i) *rolling*(ii) *sliding*
2. *In which case it is easy for the tyre to roll over?*
   (i) *rough ground* (ii) *smooth ground*

Ans: (1) In the rolling friction we need smaller force. Because the rolling friction is lesser than the sliding friction.
(2) On the smooth ground, it is easy for the tyre to roll over.

Q.16. What are advantages and disadvantages of friction? How friction can be reduced? Write any four methods.

Ans: Friction has the advantages as well as disadvantages.

Advantages of friction: Friction has following advantages.

(1) It can not be written if there would by no friction between paper and pencil.
(2) Friction enables us to walk on ground. We can not run on a slippery ground because it offers very little friction.
(3) Birds could not fly, if there is no air resistance. The reaction of pushed air enables the birds to fly.
(4) Friction is highly desirable when climbing up a hill.

Disadvantages of friction:

(1) Friction is undesirable when moving with high speeds because it opposes the motion and thus limits the speed of moving objects.
(2) Most of our useful energy is lost as heat and sound due to the friction between various moving parts of machines.
(3) In machines, friction causes wear and tear of their moving parts.

Methods of reducing friction: The friction can be reduced by:

(i) Making the sliding surfaces as smooth as possible.
(ii) Making the fast moving objects a streamline shape (fish shape) such as cars, trains and aeroplanes. This causes the smooth flow of air around their bodies. This minimizes air resistance at high speeds.

Figure 3.22: Smooth air flow at high speeds reduces air resistance

Figure 3.23: Streamlining the bullet train reduces air resistance at high speed.

(iii) Using lubricants between the sliding surfaces.
(iv) Using ball bearings or roller bearings. Because the rolling friction is much less than sliding friction.

3.4 Uniform Circular Motion

Q.17. (a) What is circular motion? Give examples.

(b) What is centripetal force? What is the direction of centripetal force? Write its examples, formula and unit.

(c) What is centripetal acceleration? Write its formula and unit.

(d) What is centrifugal force? Explain this force with example.

Ans: (a) Circular motion:

The motion of an object in a circular path is known as circular motion.

Example #1:

Take a small stone. Tie it at one end of a string and keep the other end of the string in hand as shown in given figure.

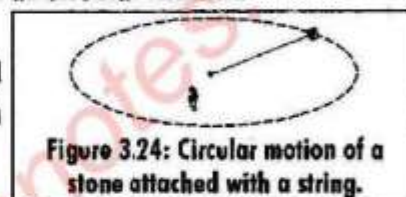



Figure 3.24: Circular motion of a stone attached with a string.

Now rotate the stone holding the string. The stone will move in a circular path.

Example #2:

The motion of the moon around the Earth in a circular orbit is an example of circular motion.

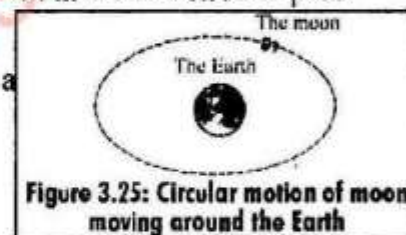



Figure 3.25: Circular motion of moon moving around the Earth

(b) Centripetal force:

Centripetal force is a force that keeps a body to move in a circle.

Explanation:

Consider a body tied at the end of a string moving with uniform speed in a circular path. The string to which the body is tied keeps it to move in a circle by pulling the body towards the centre of the circle. The string pulls the body perpendicular to its motion as shown in figure.

Thus the pulling force continuously changes the direction of motion and remains towards the centre of the circle. This centre seeking force is called the centripetal force.

Figure 3.27: (a) A string provides necessary centripetal force (b) a string is unable to provide the required centripetal force

Direction of centripetal force:

Centripetal force always acts perpendicular to the motion of body. It keeps the body to move in circle.

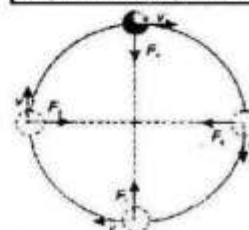



Figure 3.26: Centripetal force acting on the stone and the centrifugal force acting on the string.

Example # 1:

- A stone tied to one end of a string rotating in a circle as shown in figure. The tension in the string provides the necessary centripetal force. It keeps the stone to remain in the circle.

(a)

Figure 3.27: A string provides necessary centripetal force

- If the string is not strong enough to provide the necessary tension, it breaks and the stone moves away along a tangent to the circle as shown in given figure.

(b)

Figure 3.27: a string is unable to provide the required centripetal force

Example # 2: The moon revolves around the Earth. The gravitational force of the Earth provides the necessary centripetal force.

Formula: Centripetal force needed by a body moving in a circle depends on the mass (m) of the body, square of its velocity (v) and reciprocal to the radius (r) of the circle.

$$F_c = \frac{mv^2}{r}$$

Unit: Unit of centripetal force is newton.

(c) Centripetal acceleration: The acceleration which is produced by centripetal force is called centripetal acceleration.

Formula: Let a body of mass (m) moves with uniform speed (v) in a circle of radius (r). The acceleration a_c produced by the centripetal force F_c is given by.

$$a_c = \frac{v^2}{r}$$

Unit: Unit of centripetal acceleration is meter per second per second (ms^{-2}).

DO YOU KNOW?

While the coaster car moves around the loop, the track provides centripetal force preventing them to move away from the circle.

(d) Centrifugal force:

Centripetal reaction that pulls the string outward in sometimes called the centrifugal force.

Explanation: Consider a stone tied to a string moving in a circle as shown in the figure.

The necessary centripetal force acts on the stone through the string that keeps it to move in a circle.

According to Newton's third law of motion, there exists a reaction to the centripetal force called centrifugal force.

Centripetal reaction that pulls the string outward is sometimes called the centrifugal force.

Figure 3.28: Centripetal force acting on the stone and the centrifugal force acting on the string.

Example 3.8 ***A stone of mass 100 g is attached to a string 1m long. The stone is rotating in a circle with a speed of 5ms⁻¹. Find the tension in the string.***

Solution: $m = 100\ g = 0.1\ kg$
$v = 5\ m/s$
$r = 1m$
$T = F_c$

Tension T in the string provides the necessary centripetal force given by

$$F_c = \frac{mv^2}{r}$$

$$\therefore \quad T = \frac{0.1\ kg \times (5ms^{-1})^2}{1m}$$

$$T = 2.5\ N$$

Thus, tension in the string will be equal to 2.5 N.

Q.18. Discuss the following applications of centripetal force.
(a) Banking of the roads. (b) Washing machine dryer
(c) Cream separator

Ans: (a) Banking of the roads:

When a car takes a turn, centripetal force is needed to keep it in its curved track. The friction between the tyres and the road provides the necessary centripetal force. The car would skid if the force of friction between the tyres and the road is not sufficient enough particularly when the roads are wet. This problem is solved by banking of curved roads. Banking of a road means that the outer edge of a road is raised. Imagine a vehicle on a curved road such as shown in figure. Banking causes a component of vehicle's weight to provide the necessary centripetal force while taking a turn. Thus banking of roads prevents skidding of vehicle and thus makes the driving safe.

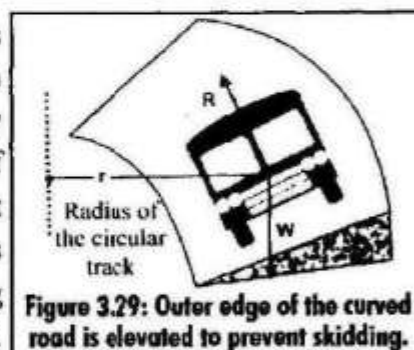



Figure 3.29: Outer edge of the curved road is elevated to prevent skidding.

(b) Washing machine dryer:

The dryer of a washing machine is basket spinners. They have a perforated wall having large numbers of fine holes in the cylindrical rotor as shown in figure. The lid of the cylindrical container is closed after putting wet clothes in it. When it spins at high speed, the water from wet clothes is forced out through these holes due to lack of centripetal force.

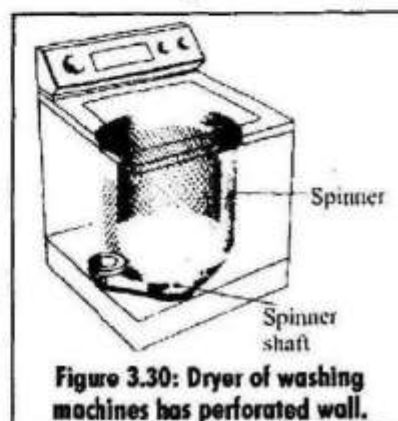



Figure 3.30: Dryer of washing machines has perforated wall.

(c) Cream separator: Most modern plants use a separator to control the fat contents of various products. A separator is a high-speed spinner. It acts on the same principle of centrifuge machines. The bowl spins at very high speed causing the heavier contents of milk to move outward in the bowl pushing the lighter contents inward towards the spinning axis. Cream or butterfat is lighter than other components in milk. Therefore, skimmed milk, which is denser than cream is collected at the outer wall of the bowl. The lighter part (cream) is pushed towards the centre from where it is collected through a pipe.

Figure 3.31: A Cream separator

SUMMARY

- A force is a push or pull. It moves or tends to move, stops or tends to stop the motion of a body.
- Inertia of a body is its property due to which it resists any change in its state of rest or uniform motion in a straight line.
- Momentum of a body is the quantity of motion possessed by the body. Momentum of a body is equal to the product of its mass and velocity.
- The force that opposes the motion of a body is called friction.
- Newton's first law of motion states that a body continues its state of rest or of uniform motion in a straight line provided no net force acts on it.
- Newton's second law of motion states that when a net force acts on a body, it produces acceleration in the body in the direction of the net force. The magnitude of this acceleration is directly proportional to the net force acting on it and inversely proportional to its mass. Mathematically, $F = ma$.
- SI unit of force is newton (N) It is defined as the force which produces an acceleration of $1\ ms^{-2}$ in a body of mass of 1 kg.
- Mass of a body is the quantity of matter possessed by it. It is a scalar quantity. SI unit of mass is kilogramme (kg).
- Weight of a body is the force of gravity acting on it. It is a vector quantity. SI unit of weight is newton (N).
- Newton's third law of motion states that to every action there is always an equal and opposite reaction.
- The acceleration and tension in a system of two bodies attached to the ends of a string that passes over a frictionless pulley such that both moves vertically are given by:

$$a = \frac{m_1 - m_2}{m_1 + m_2} g \quad ; \quad T = \frac{2m_1 m_2}{m_1 + m_2} g$$

- The acceleration and tension in a system of two bodies attached to the ends of a string that passes over a frictionless pulley such that one moves vertically and the other moves on a smooth horizontal surface are given by:

  $a = \frac{m_1}{m_1 + m_2} g$; $T = \frac{m_1 m_2}{m_1 + m_2} g$
- Law of conservation of momentum states that the momentum of an isolated system of two or more than two interacting bodies remains constant.
- A force between the sliding objects which opposes the relative motion between them is called friction.
- Rolling friction is the force of friction between a rolling body and a surface over which it rolls. Rolling friction is lesser than the sliding friction.
- The friction causes loss of energy in machines and much work has to be done in overcoming it. Moreover, friction leads to much wear and tear on the moving parts of the machine. The friction can be reduced by:
  (i) Smoothing the sliding surfaces in contact.
  (ii) Using lubricants between sliding surfaces
  (iii) Using ball bearings or roller bearings.
- The motion of a body moving along a circular path is called circular motion.
- The force which keeps the body to move in a circular path is called the centripetal force and is given by $F_c = \frac{mv^2}{r}$.
- According to Newton's third law of motion, there exists a reaction to this centripetal force. Centripetal reaction that pulls the string outward is sometimes called the centrifugal force.

SOLVED QUESTIONS

3.1 Encircle the correct answer from the given choices:

(i) Newton's first law of motion is valid only in the absence of:
(a) force (b) net force (c) friction (d) momentum

(ii) Inertia depends upon:
(a) force (b) net force (c) mass (d) velocity

(iii) A boy jumps out of a moving bus. There is a danger for him to fall:
(a) towards the moving bus (b) away from the bus
(c) in the direction of motion (d) opposite to the direction of motion

(iv) A string is stretched by two equal and opposite forces 10 N each. The tension in the string is:
(a) zero (b) 5 N (c) 10 N (d) 20 N

(v) The mass of a body:

(a) decreases when accelerated (b) increases when accelerated
(c) decreases when moving with high velocity (d) none of the above

(vi) Two bodies of masses m_1 and m_2 attached to the ends of an inextensible string passing over a frictionless pulling such that both move vertically. The acceleration of the bodies is:

(a) $\frac{m_1 \times m_2}{m_1 + m_2} g$ (b) $\frac{m_1 - m_2}{m_1 + m_2} g$ (c) $\frac{m_1 + m_2}{m_1 - m_2} g$ (d) $\frac{2m_1 m_2}{m_1 + m_2} g$

(vii) Which of the following is the unit of momentum?

(a) Nm (b) $kg\,ms^{-2}$ (c) Ns (d) Ns^{-1}

(viii) When a horse pulls a cart, the action is on the?

(a) cart (b) Earth (c) horse (d) Earth and cart

(ix) Which of the following material lowers the friction when pushed between metal plates?

(a) water (b) fine marble powder (c) air (d) oil

Ans: **1.** friction **2.** mass **3.** opposite to the direction of motion **4.** 10 N
5. none of the above **6.** $\frac{m_1 - m_2}{m_1 + m_2} g$ **7.** Ns **8.** Earth **9.** oil

3.2 Define the following terms:

(i) Inertia (ii) Momentum (iii) Force (iv) Force of friction
(v) Centripetal force

Ans: (i) Inertia: Inertia of a body is its property due to which it resists any change in its state of rest or motion.

(ii) Momentum: Momentum of a body is the quantity of motion possessed by the body. Momentum of a body is equal to the product of its mass and velocity.

(iii) Force: A force is a push or pull. It moves or tends to move, stops or tends to stop the motion of a body. The force can also change the direction of motion of a body.

(iv) Force of Friction: A force between the sliding objects which opposes the relative motion between them is called force of friction. OR

The force that opposes the motion of moving objects is called friction.

(v) Centripetal force: The force which keeps the body to move in a circular path is called the centripetal force.

$$F_c = \frac{mv^2}{r}$$

3.3 What is the difference between:

(i) Mass and weight (ii) Action and reaction
(iii) Sliding friction and rolling friction

Ans: (i) Mass and weight:

Mass	*Weight*
☆ Mass of a body is the quantity of matter that it possesses. ☆ Mass is a scalar quantity ☆ Mass remains same every where in the Earth and does not change with change of place	☆ Weight of the body is equal to the force with which Earth attracts it. ☆ Weight is a vector quantity. ☆ Weight does not remain same every where in the Earth and changes with change of place.

(ii) Action and Reaction:

Action	*Reaction*
☆ It is a force that is exerted by a body let A on the other body B is called action force.	☆ It is also a force which is exerted by the second body let B on the first body A is called reaction force.

(iii) Sliding friction and rolling friction:

Sliding friction	*Rolling friction*
☆ A force between the sliding objects which opposes the relative motion between them is called sliding friction. ☆ The magnitude of sliding friction is very large as compare to rolling friction.	☆ Rolling friction is the force of friction between a rolling body and the surface over which it rolls. ☆ The magnitude of rolling friction is very small as compare to sliding friction.

3.4 What is the law of Inertia?

Ans: Newton's first law of motion deals with the inertial property of matter, so Newton's first law of motion is also known as law of inertia.

Statement: A body continues its state of rest or of uniform motion in a straight line provided no net force acts on it.

3.5 Why is it dangerous to travel on the roof of a bus?

Ans: If a person travels on the roof of a bus, it would be dangerous because when a bus takes a sharp turn, passengers falls in the outward direction. It is due to inertia that they want continue their motion in a straight line and thus fall outwards.

3.6 Why does a passenger move outward when a bus takes a turn?

Ans: When a bus takes a sharp turn, passengers fall in the outward direction. It is due to inertia that they want to continue their motion in a straight line and thus fall outwards.

3.7 How can you relate a force with the change of momentum of a body?

Ans: When a force acts on a body, it produces acceleration in the body and will be equal to the rate of change of momentum of the body. We can write it as;

Change in momentum = final momentum - initial momentum

$P_f - P_i = mv_f - mv_i$

Thus, rate of change in momentum is given by.

$$\frac{P_f - P_i}{t} = m\left(\frac{v_f - v_i}{t}\right)$$

as, $\frac{v_f - v_i}{t} = a$

So, $\frac{P_f - P_i}{t} = ma$. ______ (I)

and Newton's second law of motion tells us that;

$F = ma$

By putting the value of F in eq. (I)

$$\boxed{\frac{P_f - P_i}{t} = F}$$ which is the required relation.

3.8 What will be the tension in a rope that is pulled from its ends by two opposite forces 100 N each?

Ans: The total tension in the rope will be:

$T = 100$ N

3.9 Action and reaction are always equal and opposite. Then how does a body move?

Ans: According to Newton's third law of motion, action and reaction are always equal and opposite in direction. But action and reaction forces always act on different bodies, so they do not cancel the effect of each other, and under this condition of forces the body moves irrespective to this, that action and reaction are equal but opposite in direction.

3.10 A horse pulls the cart. If the action and reaction are equal and opposite then how does the cart move?

Ans: As a horse pulls the cart, it is the action of the horse on the Eart, according to Newton's third law of motion, Eart also applies the equal amount of force as a reaction on the horse in opposite direction. This would be cancelled out, if both the forces act on one body, but these two forces act on two separate bodies so they would not cancel the effect of each other and the cart moves.

3.11 What is the law of conservation of momentum?

Ans: The momentum of an isolated system of two or more than two interacting bodies before and after the collisions remains the same is known as law of conservation of momentum. Let two bodies of masses m_1 and m_2 moving with velocities v_1 and v_2

respectively before collision and their velocities after collision become u_1 and u_2 respectively. According to the statement of law of conservation of momentum.

$$m_1v_1 + m_2v_2 = m_1u_1 + m_2u_2$$

3.12 Why is the law of conservation of momentum important?

Ans: Law of conservation of momentum is very much important because it is applicable on all objects in the universe either larger or smaller. This law has vast applications. According to this law the momentum of an isolated system of two or more than two interacting bodies remains same.

3.13 When a gun is fired, it recoils. Why?

Ans: Consider a system of gun and a bullet. Before firing the gun, both the gun and bullet are at rest, so the total momentum of the system is zero. As the gun is fired, bullet shoots out of the gun and acquires momentum. To conserve momentum of the system, the gun recoils. According to law of conservation of momentum, the total momentum of the gun and the bullet will also be zero after the gun is fired. Therefore the gun recoils.

3.14 Describe two situations in which force of friction is needed.

Ans: There are many conditions in which friction is desirable, two of them is given below.

(1) Friction is needed when we write, we cannot write if there would be no friction between the paper and the pencil.

(2) Friction enables us to walk on the ground, we cannot run on slippery ground. A slippery ground offers very little friction. Hence, any body who tries to run on a slippery ground may meet an accident.

3.15 How does oiling the moving parts of a machine lowers friction.

Ans: By making the sliding surfaces as smooth as possible we can reduce the friction and for this, we apply any lubricant such as oil in the moving parts of machine. It will smooth the surfaces which are sliding and hence reduces the friction between these parts of a machine.

3.16 Describe ways to reduce friction.

Ans: The friction can be reduced by:

(i) making the sliding surfaces as smooth as possible.

(ii) making the fast moving objects a streamline shape (fish shape) such as cars, trains and aeroplanes. This causes the smooth flow of air around their bodies and thus minimizes air resistance at high speeds.

(iii) using lubricants between the sliding surfaces.

(iv) using ball bearings or roller bearings. Because rolling friction is much less than sliding friction.

3.17 Why rolling friction is less than sliding friction?

Ans: All surfaces have pits and bumps and when two such surfaces are in contact. Then contact points between the two surfaces form a sort of cold welds. These cold welds resist the surfaces from sliding over each other. More is the area of in contact surfaces more would be the friction. In sliding friction more area is in contact. For example, when the axel of wheel is pushed, the force of friction between the wheel and the ground at the point of contact provides the reaction force. The reaction force acts at the contact points of the wheel in a direction opposite to the applied force. The wheel rolls with out rupturing the cold welds. That is why the rolling friction is extremely small than sliding friction.

3.18 What you know about the following:

(i) Tension in a string. *(ii) Limiting force of friction*
(iii) Braking force *(iv) Skidding of vehicles*
(v) Seatbelts *(vi) Banking of roads*
(vii) Cream separator

Ans: (i) Tension in a string: Consider a block supported by a string. The upper end of the string is fixed on a stand. Let w be the weight of the block. The block pulls the string downwards by its weight. This causes a tension "T" in the string. The tension T in the string is acting upwards at the block. As the block is at rest, therefore, the weight of the block acting downwards must be balanced by the upwards tension T in the string. Thus the tension T in the string must be equal and opposite to the weight w of the body.

(ii) Limiting force of friction: Friction is equal to the applied force that tends to move a body at rest. It increases with the applied force friction has a maximum value. It does not increase beyond this. The maximum value of friction is known as the force of limiting friction (F_s). It depends upon the normal reaction (processing force) between the two surfaces in contact. And mathematically.

$F_s = \mu R$

where co-efficient of friction = μ

R = normal reaction

F_s = force of limiting friction

(iii) Braking force: To stop a car quickly, a large force of friction between the tyres and the road is needed. But there is a limit to this force of friction that tyres can provide. If the brakes are applied too strongly, the wheels of the car will lock up (stop turning) and the car will skid due to its large momentum. It will lose its directional control that may result in an accident. In order to reduce the chance of skidding, it is advisable not to apply brakes too hard that lock up their rolling motion especially at high speeds. Force exerted by brakes is called braking force.

(iv) Skidding of vehicles: To stop a car or vehicle quickly, a large force of friction between the tyres and the roads is needed. But there is a limit to this force of friction that tyres can provide. If the brakes are applied too strongly, the wheels of the car will lock up (stop turning) and the car will skid due to its large momentum. Its directional control will be lost and it would meet an accident. In order to reduce the chance of skidding, it is advisable not to apply brakes too hard that lock up their rolling motion especially at high speed. Moreover it is unsafe to drive a vehicle with worn out tyres.

(v) Seat belts: In case of an accident, a person not wearing seatbelt will continue moving until stopped suddenly by something before him. This something may be a windscreen, another passenger or back of the seat in the front of him. Seatbelts are useful in two ways.

(1) They provide an external force to a person wearing seat belt.

(2) The additional time is required for stretching seat belts. This prolongs the stopping time for momentum to change and reduces the effect of collision.

(vi) Banking of the roads:

When a car takes a turn, centripetal force is needed to keep it in its curved track. The friction between the tyres and the road provides the necessary centripetal force. The car would skid if the force friction between the tyres and the road is not sufficient enough particularly when the roads are wet. This problem is solved by banking of curved roads. Banking of a road means that the outer edge of a road is raised. Imagine a vehicle on a curved road. Banking causes a component of vehicle's weight to provide the necessary centripetal force while taking a turn. Thus banking of roads prevents skidding of vehicle and thus makes the driving safe.

(vii) Cream separator:

Most modern plants use a separator to control the fat contents of various products. A separator is a high-speed spinner. It acts on the same principle of centrifuge machines. The bowl spins at very high speed causing the heavier contents of milk to move outward in the bowl pushing the lighter contents inward towards the spinning axis. Cream or butterfat is lighter than other components in milk. Therefore, skimmed milk, which is denser than cream is collected at the outer wall of the bowl. The lighter part (cream) is pushed towards the centre from where it is collected through a pipe.

3.19 What would happen if all friction suddenly disappears?

Ans: It there was no friction then we could not walk on the ground. Noting would be steady on the ground and it would be nearly impossible to keep things still as there would be no force to oppose an object motion. Every thing would be slide around would not be stopped. There would be no sound because the waves have to be transferred with air friction, many things would be just sliding and sliding. Infact, noting would exist in universe, without friction.

3.20 Why the spinner of a washing machine is made to spin at a very high speed?

Ans: Spinner of a washing machine is made to spin at a very high speed. Because when it spins at high speed, the water from wet clothes is forced out through these holes due to lack of centripetal force.

SOLVED PROBLEMS

3.1 A force of 20 N moves a body with an acceleration of 2 ms^{-2}. What is its mass?

Data: Force $= F = 20$ N

Acceleration $= a = 2\ ms^{-2}$

To find out: Mass = ?

Formula: $F = ma$

$$m = \frac{F}{a}$$

Solution:

$$m = \frac{20}{2}$$

$$\boxed{m = 10kg}$$

Answer: The required mass of the body is 10kg.

3.2 The weight of a body is 147 N. What is its mass? (Take the value of g as 10 ms^{-2}).

Data: Weight $= w = 147$ N

Gravitational acceleration $= g = 10\ ms^{-2}$

To find out: Mass = m = ?

Formula: $W = mg$

Solution: By putting values, we get:

$$m = \frac{w}{g}$$

$$m = \frac{147}{10}$$

$$\boxed{m = 14.7kg}$$

Answer: The required mass of the body is 14.7 kg.

3.3 How much force is needed to prevent a body of mass 10 kg from falling.

Data: Mass = m = 10 kg

Gravitational acceleration $= g = 10\ ms^{-2}$

To find out: Force = F = ?

Formula: In this case $F = w = mg$

Solution: By putting values, we get;

$$F = (10)(10)$$

$$\boxed{F = 100N}$$

Answer: The required force to prevent a body of mass 10kg is 100N.

3.4 Find the acceleration produced by a force of 100 N in a mass of 50 kg.

Data: Force = F = 100 N

Mass = m = 50 kg

To find out: Acceleration = a = ?

Formula: $F = ma$

Solution: By putting values, we get;

$$100 = (50)(a)$$

$$\frac{(100)}{50} = a$$

$$\boxed{a = 2ms^{-2}}$$

Answer: The required acceleration produced by a force is $2ms^{-2}$.

3.5 A body has weight 20 N. How much force is required to move it vertically upward with an acceleration of $2\ ms^{-2}$?

Data: Weight = w = 20 N

Acceleration = a = $2\ ms^{-2}$

To find out: Force = F = ?

Formula: $F = ma$

Solution: Firstly, we will find out the value of mass by using this formula.

$$w = mg$$

By putting values, we get;

$$\frac{20}{10} = m$$

$$m = 2kg$$

To determine the force, values are placed in the formula F = ma, we get;

$$F = (2)(2)$$

$$\boxed{F = 4N}$$

Total force = $F = F_1 + F_2$

$= 20 + 4 = 24$ N

Answer: The required force to move the body vertically upward is 24 N.

3.6 Two masses 52kg and 48kg are attached to the ends of a string that passes over a frictionless pulley. Find the tension in the string and acceleration in the bodies when both the masses are moving vertically.

Data: Gravitational acceleration $= g = 10\,ms^{-2}$

Mass of Ist body $= m_1 = 52kg$

Mass of IInd body $= m_2 = 48\,kg$

To find out: Tension $= T = ?$

Acceleration $= a = ?$

Formulas: Because both masses move vertically so formulas used in this case.

$$a = \frac{m_1 - m_2}{m_1 + m_2} g$$

$$T = \frac{2m_1\,m_2}{m_1 + m_2} g$$

Solution for acceleration.

$$a = \frac{m_1 - m_2}{m_1 + m_2} g$$

By putting values, we get:

$$a = \left(\frac{52 - 48}{52 + 48}\right) 10$$

$$a = \left(\frac{4}{100}\right) 10$$

$$a = \frac{4 \times 10}{100} = \frac{40}{100}$$

$$\boxed{a = 0.4 ms^{-2}}$$

Solution for tension:

$$T = \frac{2m_1\,m_2}{m_1 + m_2} g$$

By putting values, we get.

$$= \left[\frac{2(52)(48)}{52 + 48}\right] \times 10$$

$$= \frac{4992}{10\cancel{0}} \times 1\cancel{0} = \frac{4992}{10}$$

$$T = 499.2$$

$$\boxed{T = 500N}$$

Answers:

- The required acceleration in the bodies when both the masses are moving vertically is $0.4ms^{-2}$.
- The required tension in a string is 500N.

3.7 Two masses 26kg and 24kg are attached to the ends of a string which passes over a frictionless pulley. 26 kg is lying over a smooth horizontal table. 24 N mass is moving vertically downward. Find the tension in the string and the acceleration in the bodies.

Data: Mass of 1st body $= m_1 = 24kg$
Mass of IInd body $= m_2 = 26\ kg$
Gravitational acceleration $= g = 10\ ms^{-2}$

To find out: Tension $= T = ?$
Acceleration $= a = ?$

Formulas: In this case one body is moving horizontally on the surface of table while second body is moving vertically.

So,
$$T = \frac{m_1\ m_2}{m_1 + m_2} g$$
$$a = \frac{m_1}{m_1 + m_2} g$$

Solution for the tension:
$$T = \frac{m_1\ m_2}{m_1 + m_2} g$$

By putting values, we get.
$$T = \frac{(24)(26)(10)}{24 + 26}$$
$$T = \frac{6240}{50} = 124.8$$
$$\boxed{T = 125N}$$

Solution for acceleration:
$$a = \frac{m_1\ g}{m_1 + m_2}$$

By putting values, we get.
$$a = \frac{(24)(10)}{26 + 24} = \frac{240}{50}$$
$$\boxed{a = 4.8ms^{-2}}$$

Answers:
- The required tension in a string is 125 N.
- The required acceleration in the bodies is 4.8 ms^{-2}.

3.8 How much time is required to change 22 Ns momentum by a force of 20N?

Data: Momentum = P = 22 Ns

Force = F = 20 N

To find out: time = t = ?

Formula: $F = \frac{\Delta P}{t}$

Solution: By putting values in the formula, we get:

$$t \times 20 = 22$$

$$t = \frac{22}{20}$$

$$\boxed{t = 1.1s}$$

Answer: The required time to change momentum is 1.1s.

3.9 How much is the force of friction between a wooden block of mass 5kg and the horizontal marble floor? The coefficient of friction between wood and marble is 0.6.

Data: mass = m = 5 kg

coefficient of friction = μ = 0.6

To find out: Force of friction = F = ?

Formula: $F = \mu mg$

Solution: By putting the values in formula, we get.

$$F = (0.6)(5)(10)$$

$$\boxed{F = 30N}$$

Answer: The required force of friction between a wooden block and marble floor is 30N.

3.10 How much centripetal force is needed to make a body of mass 0.5kg to move in a circle of radius 50 cm with a speed 3 ms^{-1}?

Data: mass = m = 0.5 kg

radius = r = 50cm

$$= \frac{50}{100} = 0.5m$$

speed = v = 3 ms^{-1}

To find out: Centripetal force = F_c = ?

Formula: $F_c = \frac{mv^2}{r}$

Solution: By putting the values in formula, we get.

$$F_c = \frac{(0.5)(3)^2}{0.5}$$

$$F_c = \frac{(0.5)(9)}{0.5}$$

$$\boxed{F_c = 9\,N}$$

Answer: The requried centripetal force of body is 9N.

OBJECTIVE TYPE QUESTIONS (MCQ'S+SHORT ANSWER) FROM PREVIOUS ANNUAL PAPERS OF ALL SECONDARY BOARDS
(LAHORE, GUJRANWALA, FAISALABAD, MULTAN, SAHIWAL, SARGODHA, RAWALPINDI, D.G. KHAN And BAHAWALPUR)

3.1 Force, Inertia and Friction
3.2 Newton's Laws of Motion

☆ **Tick the correct answer.**

1. **Inertia depends upon:** (GRW. GI, FBD. GII, MLN. GI, SGD. GI, RWP. GII)
   (A) mass (B) force (C) velocity (D) weight
2. **1 Newton = ________:** (GRW. GI & GII, FBD. GII, DGK. GII, MLN. GI)
   (A) $1\,kgms^{-2}$ (B) 1 kgms (C) $1\,kgm^{-1}s^{-2}$ (D) $1\,kg^{-1}s^{-1}m^{-1}$
3. **The unit of momentum is:** (FBD. GI, SWL. GI, LHR. GII, SGD. GI & GII, BWP. GI)
   (A) Nm (B) $kgms^{-2}$ (C) Ns (D) Ns^{-1}
4. **The formula of Momentum is:** (BWP. GII)
   (A) P = Fa (B) P = mv (C) F = ma (D) F = mg
5. **Which of the following relation is corrects:** (SGD. GI)
   (A) F = m–a (B) F = ma (C) F = m/a (D) F = a/m
6. **When a horse pulls cart, the action is on the:** (LHR. GI, MLN. GII, SGD. GI,)
   (A) Cart (B) Earth (C)Horse (D) Earth and cart
7. **Newton's first law of motion is valid only in the absence of:** (LHR. GI, GRW. GI, RWP. GI)
   (A) Force (B) Net force (C) Friction (D) Momentum
8. **A string is stretched by two equal and opposite forces 10N each. The tension in the string is:** (SWL. GI)
   (A) zero (B) 5 N (C) 10 N (D) 20 N
9. **The mass of a body:** (SGD. GII, FBD. GII, MLN. GII)
   (A) Decreases when accelerated (B) Increases when accelerated

(C) Decreases when moving with high velocity (D) None of the above

10. Two bodies of masses m_1 and m_2 attached to the ends of an inextensible string passing over a frictionless pulley such that both move vertically. The acceleration of the bodies is: (SGD. GII)

(A) $\frac{m_1 \times m_2}{m_1 + m_2} g$ (B) $\frac{m_1 - m_2}{m_1 + m_2} g$ (C) $\frac{m_1 + m_2}{m_1 - m_2} g$ (D) $\frac{2m_1 m_2}{m_1 + m_2} g$

11. In SI the unit of weight is: (RWP. GI, MLN. GI)

(A) Kilogram (B) Newton (C) Meter (D) Joule

12. A mass of 6 kg is moving with acceleration of 2 ms^{-2}. Force acting on it is: (DGK. GI)

(A) 3 N (B) 4 N (C) 8 N (D) 12 N

13. Rate of change of Momentum is called: (BWP. GI & GII, GRW. GII, FBD. GI, DGK. GI)

(A) Torque (B) Distance (C) Force (D) Mass

14. In isolated system the momentum after collision of two bodies is: (LHR. GII)

(A) Increases (B) Constant (C) Decreases (D) Zero

15. The mass of a body at surface of earth is 16kg. Its weight will be: (FBD. G II)

(A) 1600N (B) 160N (C) 1.6N (D) 0.16N

16. Spring Balance is used to measure: (MLN. GI, BWP. GI)

(A) Mass (B) Temperature (C) Weight (D) Length

17. A boy jumps out of a moving bus. There is a danger for him to fall: (SWL. GII, RWP. GI)

(A) towards the moving bus (B) away from the bus
(C) in the direction of motion (D) opposite to the direction of motion

Answers

1. mass	2. $1 kg ms^{-2}$	3. Ns	4. P = mv	5. F = ma
6. Earth	7. Net force	8. 10 N	9. None of the above	10. $\frac{m_1 \times m_2}{m_1 + m_2} g$
11. Newton	12. 12 N	13. Force	14. Constant	15. 160N
16. Weight	17. opposite to the direction of motion			

☆ Give short answer to the following questions.

1. Define Law of Inertia. (LHR. GI, DGK. GI)

Ans. Newton's first law of motion deals with the inertial property of matter, so Newton's first law of motion is also known as law of inertia.

Statement: A body continues its state of rest or of uniform motion in a straight line provided no net force acts on it.

2. Define momentum and write the formula. (LHR. GI, GRW. GI, DGK. GI & GII, BWP. GI)

Ans. Momentum: Momentum of a body is the quantity of motion it possesses due to its mass and velocity.

Formula: The momentum P of a body is given by the product of its mass (m) and its velocity (v).

$$P = mv$$

3. Define inertia. (FBD. GI, MLN. GII LHR. GII)

Ans. Inertia of a body is its property due to which it resists any change in its state of rest or motion.

4. Differentiate between force and inertia. (DGK. GII, BWP. GII)

Ans. Force: A force is a push or pull. It moves or tends to move, stops or tends to stop the motion of a body. The force can also change the direction of motion of a body.

Inertia: Inertia of a body is its property due to which it resists any change in its state of rest or motion.

5. What is meant by dynamics? (GRW. GII)

Ans. The branch of mechanics that deals with the study of motion of an object and the causes of its motion is called dynamics.

6. Give two differences between mass and weight.

Ans. Mass: (LHR. GI & GII, MLN. GII, SGD. GI & GII, SWL. GI, DGK. GII, BWP. GI)

☆ Mass of a body is the quantity of matter that it possesses.

☆ Mass is a scalar quantity

Weight:

☆ Weight of the body is equal to the force with which Earth attracts it.

☆ Weight is a vector quantity.

7. What is the relation between force and momentum? (FBD. GI, MLN. GII, RWP. GII)

Ans. When a force acts on a body, it produces acceleration in the body and will be equal to the rate of change of momentum of the body. We can write it as;

Change in momentum = final momentum - initial momentum

$P_f - P_i = mv_f - mv_i$

Thus, rate of change in momentum is given by.

$$\frac{P_f - P_i}{t} = m\left(\frac{v_f - v_i}{t}\right)$$

as, $\frac{v_f - v_i}{t} = a$

So, $\frac{P_f - P_i}{t} = ma$. ______ (1)

and Newton's second law of motion tells us that;

$F = ma$

By putting the value of F in eq. (I)

$\boxed{\frac{P_f - P_i}{t} = F}$ which is the required relation.

8. State Newton's First Law of Motion. (MLN. GI, SWL. GI, DGK. GI)

Ans. "A body continues its state of rest or of uniform motion in a straight line provided no net force acts on it."

9. Give Law of Conservation of Momentum. (MLN. GI, BWP. GII, FBD. GII, RWP. GII)

Ans. Law of Conservation of Momentum: The momentum of an isolated system of two or more than two interacting bodies before and after the collisions remains the same is known as law of conservation of momentum. Let two bodies of masses m_1 and m_2 moving with velocities v_1 and v_2 respectively before collision and their velocities after collision become u_1 and u_2 respectively. According to the statement of law of conservation of momentum.

$$\boxed{m_1v_1 + m_2v_2 = m_1u_1 + m_2u_2}$$

10. Define Newton's third law of motion. Give an example. (SWL. GI, GRW. GI)

Ans. Newton's third law of motion: "To every action there is always an equal but opposite reaction."

Example: Take an air-filled balloon. When the balloon is set free, the air inside it rushes out and the balloon moves forward.

11. What will be the tension in a string that is pulled from its ends by two opposite forces 100N each? (SWL. GII)

Ans. The tension is the string is 100 N.

12. State second law of Motion. (SGD. GI, BWP. GII)

Ans. Statement: When a net force acts on a body, it produces acceleration in the body in the direction of the net force. The magnitude of this acceleration is directly proportional to the net force acting on the body and inversely proportional to its mass.

13. Prove that: F = ma (RWP. GI, SGD. GI)

Ans. If a force produces an acceleration "a" in a body of mass "m" then it can be stated mathematically that

$a \propto F$ ________ (i)

$a \propto \frac{1}{m}$ ________ (ii)

By combining eq. (i) and (ii)

$$a \propto \frac{F}{m}$$

$$a = K\frac{F}{m}$$

$$F = ma \qquad \because k = 1$$

14. When a gun is fired, it recoils. Why? (RWP. GII, BWP. GII, FBD. GI, MLN. GI)

Ans. Consider a system of gun and a bullet. Before firing the gun, both the gun and bullet are at rest, so the total momentum of the system is zero. As the gun is fired, bullet shoots out of the gun and acquires momentum. To conserve momentum of the system, the gun recoils. According to law of conservation of momentum, the total momentum of the gun and the bullet will also be zero after the gun is fired. Therefore the gun recoils.

15. What is Atwood Machine? Give its one use. (DGK. GI, BWP. GI, MLN. GI)

Ans. Atwood machine: An atwood machine is an arrangement of two objects of unequal masses. Both the objects are attached to the ends of a string. The string passes over a frictionless pulley. This arrangement is sometime used to find the acceleration due to gravity by the following formula.

$$g = \frac{m_1 + m_2}{m_1 - m_2} a$$

16. A body of mass 5kg is moving with a velocity of 10 ms⁻¹. Find the force required to stop it in 2 seconds. (DGK. GII)

Ans.

$m = 5\ kg$

$v_i = 10\ ms^{-1}$

$v_f = 0\ ms^{-1}$

$t = 2\ s$

$F = ?$

$P_i = mv_i$

$P_i = 5\ kg \times 10\ ms^{-1}$

$= 50\ Ns$

$P_f = mv_f$

$P_f = 5\ kg \times 0\ ms^{-1}$

$= 0\ Ns$

Since $F = \frac{P_i - P_f}{t}$

$= \frac{50Ns - 0Ns}{2s}$

$F = 25N$

Thus 25 N, force is required to stop the body.

17. Why first law of Motion is called Law of Inertia? **(BWP. GI)**

Ans. Newton's first law of motion deals with the inertial property of matter, therefore, Newton's first law of motion is also known as law of inertia.

18. The weight of a body is 147N. what will be its mass? (Value of g is $10ms^{-1}$) **(LHR. GII)**

Sol. Weight $= w = 147$ N

Gravitational acceleration $= g = 10 ms^{-2}$

To find out: Mass $= m = ?$

Formula: $W = mg$

$$m = \frac{w}{g}$$

Solution: By putting values, we get:

$$\frac{147}{10} = m$$

$$\boxed{m = 14.7kg}$$

Ans: The required mass of the body is 14.7 kg.

19. Find the acceleration produced by a force of 100N in a mass of 50kg. **(GRW. GII, FBD. GII, SWL. GI, SGD. GII, RWP. GII)**

Sol. Force $= F = 100$ N

Mass $= m = 50$ kg

To find out: Acceleration $= a = ?$

Formula: $F = ma$

Solution: By putting values, we get;

$$100 = (50)(a)$$

$$\frac{(100)}{50} = a$$

$$\boxed{a = 2ms^{-2}}$$

Ans: The required acceleration produced by a force is $2ms^{-2}$.

20. Define force and its SI unit. **(RWP. GI, FBD. GI & GII, DGK. GI)**

Ans. Force: A force is a push or pull. It moves or tends to move, stops or tends to stop the motion of a body. The force can also change the direction of motion of a body.

Unit: In SI, unit of force is Newton (N).

Newton: One newton (1N) is the force that produces an acceleration of $1ms^{-2}$ in a body of mass of 1 kg.

21. How much force is needed to prevent a body of mass 10kg from falling? (RWP. GI)

Data. Mass = m = 10 kg

Gravitational acceleration = g = $10ms^{-2}$

To find out: Force = F = ?

Formula: In this case F = w = mg

Solution: By putting values, we get;

F = (10) (10)

F = 100N

Ans: The required force to prevent a body of mass 10kg is 100N.

3.3 The Circular Motion

3.4 Uniform Circular Motion

☆ **Tick the correct answer.**

1. **Which of the following materials lowers friction when pushed between metal plates:** (LHR. GI & GII, FBD. GI, MLN. GII, RWP. GI)
   (A) Water (B) Fine marble powder (C) Air (D) Oil
2. **Coefficient of friction between tyre and dry road is:** (GRW. GI)
   (A) 0.6 (B) 1 (C) 0.05 (D) 0.2
3. **The maximum value of friction is called:** (RWP. GI)
   (A) Cold Welds (B) Normal reaction
   (C) Limiting friction (D) Kinetic friction
4. **The value of co-efficient of friction between ice and wood is:** (RWP. G I)
   (A) 0.29 (B) 0.05 (C) 0.2 (D) 1.0
5. **The force that opposes the motion of moving objects is called:** (FBD. GII, DGK. GI)
   (A) Inertia (B) Centripetal force (C) Friction (D) Centrifugal force
6. **When the cyclist stops pedaling, bicycle stops due to?** (SWL. GI)
   (A) friction (B) momentum (C) weight (D) mass
7. **Centripetal force always act ______ to the motion of body:** (SWL. GI, GRW. G II)
   (A) opposite (B) parallel (C) perpendicular (D) at an angle of 45°
8. **Formula to find the centripetal acceleration is:** (DGK. GI, SWL. GI, SGD. GII)
   (A) $\frac{v^2}{r}$ (B) $\frac{v^2}{r^2}$ (C) $\frac{v}{r^2}$ (D) $\frac{mv}{r}$
9. **A force that keeps a body to move in a circle is called the force of:** (DGK. GII)
   (A) Gravitational (B) Centripetal (C) Centrifugal (D) Field

10. Formula to determine Centripetal Force is: **(BWP. GI, FBD. GI, SWL. GII)**

(A) $\frac{mv^2}{r}$ (B) $\frac{m^2v}{r}$ (C) $\frac{mr^2}{v}$ (D) $\frac{mv}{r^2}$

11. If velocity of the body becomes double, then centripetal force will be: **(RWP. GII)**

(A) Half (B) Three times greater
(C) Double (D) Four times greater

Answers

1. Oil 2. 1 3. Limiting friction 4. 0.05 5. Friction
6. friction 7. perpendicular 8. $\frac{v^2}{r}$ 9. Centripetal 10. $\frac{mv^2}{r}$
11. Four times greater

☆ Give short answer to the following questions.

1. Describe two ways to reduce friction. **(LHR. GII, FBD. GII, BWP. GII, MLN. GII)**

Ans. The friction can be reduced by:

(i) Making the sliding surfaces as smooth as possible.

(ii) Making the fast moving objects a streamline shape (fish shape) such as cars, trains and aeroplanes. This causes the smooth flow of air around their bodies and thus minimizes air resistance at high speeds.

2. Why rolling friction is less than sliding friction? **(LHR. GII, DGK. GII, BWP. GI)**

Ans. All surfaces have pits and bumps and when two such surfaces are in contact. Then contact points between the two surfaces form a sort of cold welds. These cold welds resist the surfaces from sliding over each other. More is the area of in contact surfaces more would be the friction. In sliding friction more area is in contact. For example, when the axel of wheel is pushed, the force of friction between the wheel and the ground at the point of contact provides the reaction force. The reaction force acts at the contact points of the wheel in a direction opposite to the applied force. The wheel rolls with out rupturing the cold welds. That is why the rolling friction is extremely small than sliding friction.

3. What type of shoes are better for jogging and why? **(GRW. GI)**

Ans. The rough surface shoe is better for jogging. Because it suffer more friction and prevent from sliping.

4. What is meant by coefficient of friction? Write its mathematical form.

Ans. Co-efficient of friction: **(GRW. GII, GRW. GI)**

The ratio between the force of limiting friction F_S and normal reaction R is constant. This constant is called the co-efficient of friction and is represented by μ.

Formula: $\mu = \frac{F_s}{R}$

If m is the mass of the block, then for horizontal surface

$R = mg$

$F_s = \mu mg$

$\frac{F_s}{mg} = \mu$

5. Differentiate between sliding friction and rolling friction. (SWL. GII, FBD. GII)

Ans. Sliding friction:

☆ A force between the sliding objects which opposes the relative motion between them is called sliding friction.

☆ The magnitude of sliding friction is very large as compare to rolling friction.

Rolling friction:

☆ Rolling friction is the force of friction between a rolling body and the surface over which it rolls.

☆ The magnitude of rolling friction is very small as compare to sliding friction.

6. Write down any two advantages and disadvantages of friction.

(GRW. GI, MLN. GI, FBD. GI, SWL. GI & GII, RWP. GI)

Ans. Advantages of friction:

(i) It can not be written if there would be no friction between paper and pencil.

(ii) Friction enables us to walk on ground. We can not run on a slippery ground because it offers very little friction.

Disadvantages of friction:

(i) Friction is undesirable when moving with high speeds because it opposes the motion and thus limits the speed of moving objects.

(ii) Most of our useful energy is lost as heat and sound due to the friction between various moving parts of machines.

7. What is meant by rolling friction? (GRW. GII, MLN. GII)

Ans. Rolling friction is the force of friction between a rolling body and a surface over which it rolls. Rolling friction is much smaller than the sliding friction.

8. What is the reason for sliping on wet ground? Explain. (FBD. GI)

Ans. Friction enables us to walk on wet ground. We cannot run on a slippery ground because it offers very little friction.

9. Define friction and write equation. (SWL. GI, FBD. GII)

Ans. The force that opposes the motion of moving objects is called friction.

i.e. $F = \mu R$

10. How does cream separator work? **(GRW. GII, RWP. GI & GII)**

Ans. A separator is a high-speed spinner. It acts on the same principle of centrifuge machines. The bowl spins at very high speed causing the heavier contents of milk to move outward in the bowl pushing the lighter contents inward towards the spinning axis. Cream or butterfat is lighter than other components in milk. Therefore, skimmed milk, which is denser than cream is collected at the outer wall of the bowl. The lighter part (cream) is pushed towards the centre from where it is collected through a pipe.

11. Define and write down equation of centripetal force.

(SGD. GI & GII, LHR. GI, RWP. GI, BWP. GI)

Ans. Centripetal force: The force which keeps the body to move in a circular path is called the centripetal force.

$$F_c = \frac{mv^2}{r}$$

12. Define Centripetal Force and Circular Motion. **(BWP. GII)**

Ans. Centripetal force:

The force which keeps the body to move in a circular path is called the centripetal force.

$$F_c = \frac{mv^2}{r}$$

Circular motion:

The motion of an object in a circular path is known as circular motion.

13. Define the centrifugal force. **(LHR. GI)**

Ans. Centripetal reaction that pulls the string outward is sometimes called the centrifugal force.

TURNING EFFECT OF FORCES

STUDENTS LEARNING OUTCOMES

After studying this unit, the students will be able to:

- define like and unlike parallel forces.
- state head to tail rule of vector addition of forces/vectors
- describe how a force is resolved into its perpendicular components.
- determine the magnitude and direction of a force from its perpendicular components.
- define moment of force or torque as moment = force x perpendicular distance from pivot to the line of action of force.
- explain the turning effect of force by relating it to everyday life.

- state the principle of moments.
- define the centre of mass and centre of gravity of a body.
- define couple as a pair of forces tending to produce rotation.
- prove that the couple has the same moments about all points.
- define equilibrium and classify its types by quoting examples from everyday life.
- state the two conditions for equilibrium of a body.
- solve problems on simple balanced systems when bodies are supported by one pivot only.
- describe the states of equilibrium and classify them with common examples.
- explain effect of the position of the centre of mass on the stability of simple objects.

Conceptual Linkage

This chapter is built on

Lever	– Science - V
Machines	– Science - VI
Kinematics	– Physics-IX
Trigonometry	– Maths-IX

This chapter leads to:
Rotational Motion, Vectors and Equilibrium —Physics-XI

INVESTIGATION SKILLS:

- determine the position of centre of mass/gravity of regularly and irregularly shaped objects.

SCIENCE, TECHNOLOGY AND SOCIETY CONNECTION:

- illustrate by describing a paractical application of moment of force in the working of bottle opener, spanner, door/windows handles etc.
- describe the working principle of see-saw.

Major Concepts:

4.1 Forces on bodies
4.2 Addition of Forces
4.3 Resolution of Forces
4.4 Moment of a Force
4.5 Principle of moments
4.6 Centre of mass
4.7 Couple
4.8 Equilibrium
4.9 Stability

- demonstrate the role of couple in the steering wheels and bicycle pedals.
- demonstrate through a balancing toy, racing car etc. that the stability of an object can be improved by lowering the centre of mass and increasing the base area of the objects.

Figure 4.1: We can loose a nut with a spanner.

Can the nut of the axle of a bike be loosened with hand? Normally we use a spanner as shown in figure 4.1. A spanner increases the turning effect of the force.

Figure 4.2: Children carrying pitchers on thier heads.

Look at the picture on the previous page. What is the joker doing? He is trying to balance himself on a wooden plank which is placed over a cylindrical pipe. Can we do the same? A baby gradually learns to stand by balancing herself. Women and children in the villages often carry pitchers with water on their heads such as shown in figure 4.2. With a little effort we can learn to balance a stick vertically up on our finger tip. Balanced objects are said to be in equilibrium. In this unit, we will learn many interesting concepts such as torque, equilibrium, etc. their applications in daily life.

4.1 Like and Unlike Parallel Forces

Q.1. What are parallel forces? Explain. What are the types of parallel forces? Give example to support you answer.

Ans: Parallel forces:

The forces which are parallel to each other are called parallel forces.

Explanation:

Many objects in our surrounding are observed by us on which many forces are acting. It is found that all or some of the forces acting on a body in the same direction.

For example, many people push a bus in the same direction to start it. All these forces are parallel to each other.

Types of parallel forces:

There are two types of parallel forces.

(i) Like parallel forces (ii) Unlike parallel forces

(I) Like parallel forces:

Like parallel forces are the forces that are parallel to each other and have the same direction.

Example # 1:

Given figure shows a bag with apples in it. The weight of the bag is due to the

weight of all the apples in it. Since the weight of every apple in the bag is the force of gravity acting on it vertically downwards, therefore, weights of apples are the parallel forces. All these forces are acting in the same direction, so called parallel forces.

Weight of each apple
Figure 4.3: Like parallel forces

Example # 2:

In the given figure two forces are acting on a body. These forces are representing by F_1 and F_2. Both forces have same direction so these are called parallel forces.

F_1 F_2

(ii) Unlike parallel forces:

Unlike parallel forces are the forces that are parallel but have directions opposite to each other.

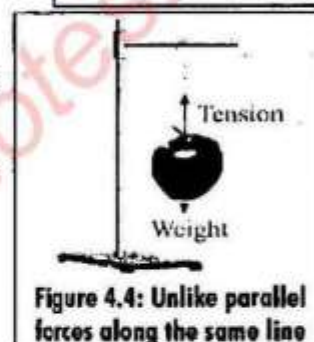
Example # 1: In the given figure an apple is suspended by a string. The string is stretched due to weight of the apple.

Two forces are acting in this case.

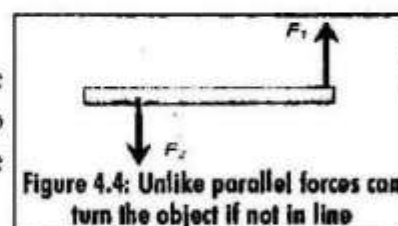
(i) **Weight** of the apple acting vertically downwards.

(ii) **Tension** in the string pulling it vertically upwards.

Tension
Weight
Figure 4.4: Unlike parallel forces along the same line

These two forces are parallel but opposite to each other so called unlike parallel forces.

Example # 2:

In the given figure, forces F_1 and F_2 are unlike parallel forces, because they are parallel and opposite to each other. But F_1 and F_2 are not acting along the same line and hence they are capable to rotate the body.

Figure 4.4: Unlike parallel forces can turn the object if not in line

4.2 Addition of forces

Q.2. What is the resultant force? How vectors can be added by head to tail rule? Explain your answer.

Ans: Resultant force: A resultant force is a single force that has the same effect as the combined effect of all the forces to be added.

Vector quantity: Force is a vector quantity. It has both magnitude and direction.

Addition of forces: Forces are not added by ordinary arithmetical rules. When forces are added we get a resultant force.

> **It should be noted that head to tail rule can be used to add any number of forces. The vector representing resultant force gives the magnitude and direction of the resultant force.**

One of the methods for the addition of forces is a graphical method. In this method forces can be added by head to tail rule of vector addition.

Addition of vectors: Vectors are not added by ordinary arithmetical rules. The vectors can be added by head to tail rule.

Head to tail rule: A graphical method is used to find the resultant of two or more forces or vectors, called the head to tail rule.

Explanation: Given figure shows a graphical method of vector addition.

Head to tail rule method can be understood stepwise.

(1) First select a suitable scale

(2) Draw the vectors of all the forces according to the scale; such as vectors **A** and **B**.

(3) Take any one of the vectors as first vector e.g., vector **A**.

(4) Draw next vector **B** such that its tail coincides with the head of the first vector **A**.

(5) Draw the next vector for the third force (if any) with its tail coinciding with the head of the previous vector and so on.

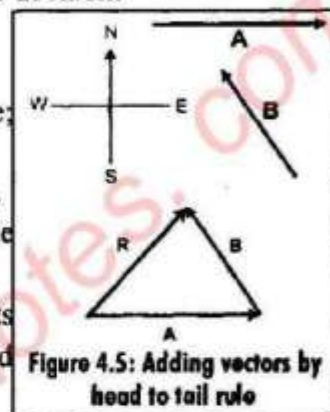



Figure 4.5: Adding vectors by head to tail rule

(6) Draw a vector **R** as shown in the figure. The tail of vector **R** is at the tail of vector **A**, the first vector, while its head is at the head of vector B, the last vector.

Vector **R** represents the resultant force completely in magnitude and direction.

Example 4.1 ***Find the resultant of three forces 12 N along x-axis, 8N making an angle of 45° with x-axis and 8N along y-axis.***

Solution: Here $\mathbf{F}_1$ = 12 N along x-axis

$\mathbf{F}_2$ = 8 N along 45° with x - axis.

$\mathbf{F}_3$ = 8 N along y-axis

Scale: 1 cm = 2N

(i) Represent the forces by vectors $\mathbf{F}_1$, $\mathbf{F}_2$ and $\mathbf{F}_3$ according to the scale in the given direction.

(ii) Arrange these forces $\mathbf{F}_1$, $\mathbf{F}_2$ and $\mathbf{F}_3$. The tail of force $\mathbf{F}_2$ coincides with the head of force $\mathbf{F}_1$ at point B as shown in figure. Similarly the tail of force $\mathbf{F}_3$ coincides with the head of force $\mathbf{F}_2$ at point C.

(iii) Join points A to D. Point A is the tail of the force $\mathbf{F}_1$ and point D is the head of force $\mathbf{F}_3$. According to head to tail rule, force **F** represents the resultant force.

(iv) Measure the vector AD.

(v) Multiply length of the force **F** by the scale (2Ncm^{-1}) to find the magnitude of the resultant force **F**.

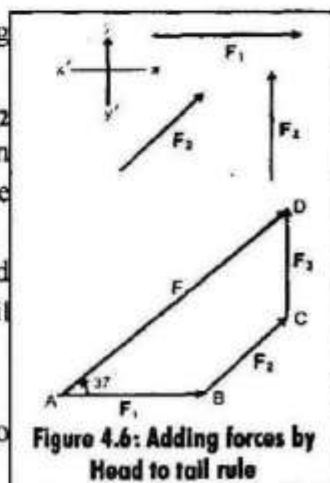



Figure 4.6: Adding forces by Head to tail rule

(vi) Measure the angle $\angle DAB$ using a protractor which the force **F** makes with x-axis to find the direction of resultant force.

4.3 Resolution of Forces

Q.3. What are perpendicular components? How resolution of forces can be defined? Explain the process of resolution of forces? Also find out the value of x and y component of a force?

Ans: Perpendicular components: If a force is formed from two mutually perpendicular components then such components are called its **perpendicular components.**

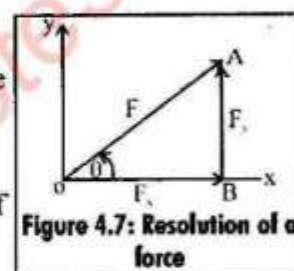
Resolution of forces: Splitting up of a force into two mutually perpendicular components is called the resolution of that force.

Explanation:

(i) Consider a force **F** represented by line **OA** making an angle θ with x-axis as shown in given figure.

(ii) From point **A**, draw a perpendicular **AB** on x-axis

(iii) According to head to tail rule, **OA** is the resultant of vectors represented by **OB** and **BA**.

Figure 4.7: Resolution of a force

Formula of resultant force:

$$OA = OB + BA$$

Resultant force = x-component + y-component

In the above figure **OB** represents x-component F_x and **BA** represents its y-component F_y.

$$F = F_x + F_y$$

Perpendicular components: In the above figure components **OB** and **AB** are perpendicular to each other. They are called the perpendicular components of **OA** representing force A.

Vaule of x-component (F_x): Value of x-component (F_x) of vector **(F)** can be found by using the trigonometric ratios.

In right angled triangle OBA

$$\cos\theta = \frac{\text{Base}}{\text{Hypotenuse}}$$

$$\cos\theta = \frac{OB}{OA}$$

$$\cos\theta = \frac{F_x}{F}$$

$$F\cos\theta = F_x$$

so, $\boxed{F_x = F\cos\theta}$ ______ (1)

Ratio\θ	0°	30°	45°	60°	90°
sin θ	0	0.5	0.707	0.866	1
cos θ	1	0.866	0.707	0.5	0
tan θ	0	0.577	1	1.732	∞

Value of y-component (F_y):

Value of y-component (F_y) of force (F) can be found by using the trigonometric ratios.

In right angled triangle;

$$\sin\theta = \frac{\text{perpendicular}}{\text{Hypotenuse}}$$

$$\sin\theta = \frac{BA}{OA}$$

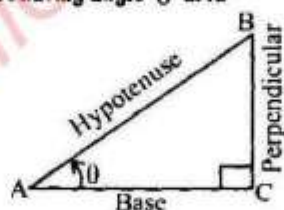
$$\sin\theta = \frac{F_y}{F}$$

$$F\sin\theta = F_y$$

so, $\boxed{F_y = F\sin\theta}$ ____ (2)

Equations (1) and (2) give the perpendicular components F_x and F_y respectively

Some Trignometric Ratios

The ratios between any of its two sides of a right angled triangle are given certain names such as sine, cosine etc. Consider a right angled triangle $\triangle ABC$ having angle θ at A.

$$\sin\theta = \frac{\text{Perpendicular}}{\text{Hypotenuse}} = \frac{BC}{AB} \quad \cos\theta = \frac{\text{Base}}{\text{Hypotenuse}} = \frac{AC}{AB} \quad \tan\theta = \frac{\text{Perpendicular}}{\text{Base}} = \frac{BC}{AC}$$

Example 4.2 ***A man is pulling a trolley on a horizontal road with a force of 200 N making 30° with the road. Find the horizontal and vertical components of its force.***

Solution:

F = 200 N

θ = 30° with the horizontal

F_x = ?

F_y = ?

Since $F_x = F\cos\theta$

or $F_x = 200 \times \cos 30^\circ$

$F_x = 200 \times 0.866$

$= 173.2\ N$

Similarly $F_y = F\sin\theta$

or $F_y = 200 \times \sin 30^\circ$

$= 200 \times 0.5$

$= 100\ N$

Thus, horizontal and vertical components of the pulling force are 173.2 N and 100 N respectively.

Mini Exercise

In a right angled traingle lenght of base is 4cm and its perpendicular is 3cm.

Find: (i) Length of hypotenuse (ii) $\sin\theta$ (iii) $\cos\theta$ (iv) $\tan\theta$

Ans: **(i) Length of hypotenuse:**

$(Hypotenuse)^2 = (Base)^2 + (Perpendicular)^2 \rightarrow$ (i)

According to given situation a triangle is drawn as shown in figure.

Base = 4cm

Perpendicular = 3cm

The value of hypotenuse can be found out by using eq (i).

$(Hypotenuse)^2 = (4)^2 + (3)^2$

$(Hypotenuse)^2 = 16 + 9$

$(Hypotenuse)^2 = 25$

By taking under root on both side:

$\sqrt{(Hypotenuse)^2} = \sqrt{(25)}$

$\boxed{Hypotenuse = 5cm}$

(ii) As we know.

$\sin\theta = \frac{Perpendicular}{Hypotenuse}$

$\sin\theta = \frac{3}{5}$

$\sin\theta = 0.6$

(iii) As we know:

$\cos\theta = \frac{Base}{Hypotenuse}$

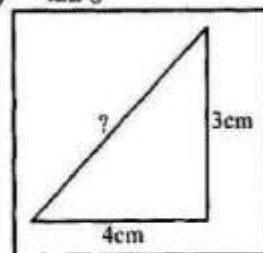
$\cos\theta = \frac{4}{5}$

$\cos\theta = 0.8$

(iv) As we know:

$\tan\theta = \frac{Perpendicular}{Base}$

$\tan\theta = \frac{3}{4}$

$\tan\theta = 0.75$

Q.4. How magnitude and direction of a force from its perpendicular components can be found? Explain.

Ans: Determination of the force:

A force can be resolved into two perpendicular components. Its reverse is to determine the force knowing its perpendicular components.

(i) Consider $\mathbf{F}_x$ and $\mathbf{F}_y$ as the perpendicular components of a vector $\mathbf{F}$.

(ii) These perpendicular components F_x and F_y are represented by lines **OP** and **PR** respectively as shown in the figure.

Figure 4.8: Determination of a force by its perpendicular components

According to head to tail rule:

According to head to tail rule

$$OR = OP + PR$$

(i) According to Figure **OR** represents the force.

(ii) **OP** represent the x-component of the force (F_x).

(iii) **PR** represents the y-component of the force (F_y).

So; $\quad F = F_x + F_y$

Magnitude of Force F: The magnitude of the force **F** can be determined using the right angled triangle OPR.

$$(\text{Hypotenuse})^2 = (\text{Base})^2 + (\text{Perpendicular})^2$$
$$(OR)^2 = (OP)^2 + (PR)^2$$
$$F^2 = F_x^2 + F_y^2$$
$$F = \sqrt{F_x^2 + F_y^2}$$

Direction of Force F:

The direction of force **F** with x-axis is given by using the trigonometric ratio.

$$\tan\theta = \frac{\text{perpendicular}}{\text{Base}}$$
$$\tan\theta = \frac{PR}{OP}$$
$$\tan\theta = \frac{F_y}{F_x}$$
$$\theta = \tan^{-1}\frac{F_y}{F_x}$$

4.4 Torque or moment of a force

Q.5. How will you define rigid body, axis of rotation and torque. Explain your answer with examples.

Ans: Rigid body:

A body is composed of large number of small particles. If the distances between all pairs of particles of the body do not change by applying a force then it is called a rigid body.

OR

A rigid body is the one that is not deformed by force or forces acting on it.

Axis of rotation: Consider a rigid body. As it rotates, its particles move in fixed circles. A fixed line that passes through the centres of these circles is called axis of rotation of the body.

Example: When a door is opened or closed by pushing or pulling it. Push or pull turn the door about its hinge or axis of rotation.

Figure 4.9: It is easy to open and close the door by pulling or pushing it at its handle.

Torque: The turning effect of a force is called torque or moment of the force.

Examples:

(i) When a door is opened or closed by pushing or pulling it. It is only due to the turning effect on the force acting on it.

(ii) Turning pencil in a sharpener

(iii) Turning stopcock of a water tap.

(iv) Turning door knob

Figure 4.10: Turning effect of forces

The Location where force is applied in the case of torque:

A door can opened or closed more easily by applying a force at the outer edge of a door rather near the hinge. Thus, the location where the force is applied to turn a body is very important.

Factors on which torque depends:

The factors on which torque or moment arm depends are given below.

(1) Force (2) Moment arm

Explanation: It might have seen by us that a mechanic uses a spanner as shown in figure to loosen or tighten a nut or a bolt.

A spanner having long arm helps him to do it with greater ease than the one having short arm. It is because the turning effect is different in the two cases.

The relation of torque and moment arm: The torque produced by a force using a spanner of longer arm is greater than the torque produced by the same force but using a spanner of shorter arm.

Moment arm
Force
Moment arm
Force

Figure 4.11: It is easy to tighten a nut using a spanner of longer arm than a spanner of shorter arm.

Q.6. What is torque? On which factors it depends? Define these factors? What is the formula and unit of the torque?

Ans: Torque: The turning effect of a force is called torque or moment of force.

Factors on which torque depends: Torque depends on two factors.

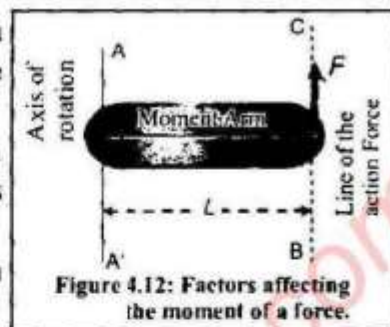
(i) Line of action of force

(ii) Moment arm

(i) Line of action of force: The line along which a force acts is called the line of action of the force. In the given figure line BC is the line of action of the force (F).

(ii) Moment arm: The perpendicular distance between the axis of rotation and the line of action of the force is called the moment arm of the force.

Moment arm is represented by distance (L) in given figure.

Figure 4.12: Factors affecting the moment of a force.

Relation of force and torque: Torque and force are directly proportional to each other. Greater is the force, greater is the moment of the force or torque.

Relation of moment arm and Torque:

Torque and moment arm are directly proportional to each other. So longer is the moment arm, greater is the moment of the force or torque.

Formula: The moment of the force or torque τ is determined by the product of force F and its moment arm L.

Mathematically

Torque $\tau = LF$

Unit: SI unit of torque is newton-metre (Nm). A torque of 1 Nm is caused by a force of 1N acting perpendicular to the moment arm 1 m long.

4.5 Principle of moments

Q7. Explain the principle of moments.

Ans: Principle of moment:

A body is balanced if the sum of clockwise moments acting on the body is equal to the sum of anticlockwise moments on it. **OR**

A body initially at rest does not rotate if sum of all clockwise moments acting on it is balanced by the sum of all the anticlockwise moments acting on it. This is known as the principle of moments.

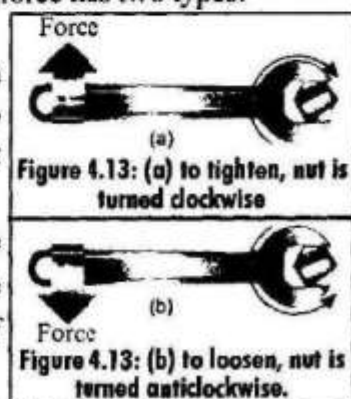
Types of principle of moments: A torque or moment of the force has two types.

(i) Clockwise moment (ii) Anticlockwise moment

Example of clockwise moment: A force that turns a spanner in the clockwise direction is generally used to tighten a nut as shown in figure (a). The torque or moment of the force so produced is called clockwise moment.

Example of anticlockwise moment: To loosen a nut, the force is applied such that it turns the nut in the anticlockwise direction as shown in figure (b). The torque or moment of the force so produced is called anticlockwise moment.

Figure 4.13: (a) to tighten, nut is turned clockwise

Figure 4.13: (b) to loosen, nut is terned anticlockwise.

QUICK QUIZ:

Name some more objects that work by the turning effects of forces.

Ans:

(1) Torque is produced when a force is applied to paddle of a bicycle. Because by applying force its wheels experience the rotational effect.

(2) Torque is produced when a force is applied to the door to open.

QUICK QUIZ:

1. **Can a small child play with a fat child on the see-saw? Explain how?**

Ans: Yes, they can play on see saw, the fat child has larger weight that's mean larger force and smaller child has smaller weight and smaller force. So in order to play, larger weight should be at smaller distance from the centre of the see saw and the smaller weight should be at larger distance from the centre of the see saw. In another situation a fat child cannot play with a small child if they have equal distances from the centre see-saw.

Figure 4.14: Children on see-saw.

2. **Two children are sitting on the see-saw, such that they can not swing. What is the net turque in this situation?**

Ans: Net torque in this situation is zero. Because clockwise torque will cancel the effect of anticlockwise torque.

MINI EXERCISE

A force of 150 N can loosen a nut when applied at the end of a spanner 10 cm long.

1. **What should be the length of the spanner to loosen the same nut with a 60 N force?**
2. **How much force would be sufficient to loosen it with a 6 cm long spanner?**

Data:

Force = 150 N

Length = 10cm = 0.1cm

$\tau = F \times \ell$

$\tau = 150 \times 0.1$

$\tau = 15N$

Ans: (1) Length = ?

$F = 60N$

$\tau = 15N$

As we know

$\tau = F \times \ell$

$15 = 60 \times \ell$

$\frac{15}{60} = \ell$

$\ell = 0.25m$

$\ell = 0.25 \times 100$

$\ell = 25cm$

(2) Force = ?

Length $= \ell = 6cm$

$= \frac{6}{100} = 0.06m$

$\tau = 15N$

$\tau = F \times \ell$

$15 = F \times 0.06$

$\frac{15}{0.06} = F$

$\boxed{F = 250N}$

Example 4.4

A metre rod is supported at its middle point O as shown in figure. The block of weight 10N is suspended at point B, 40 cm from O. Find the weight of the block that balances it at point A, 25cm from O.

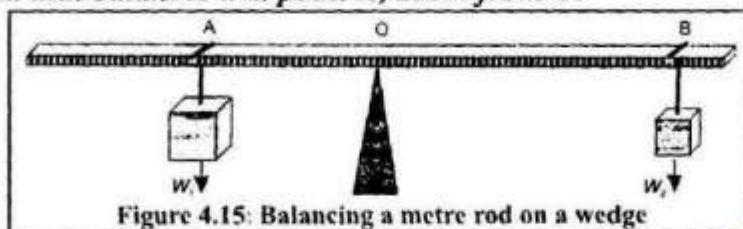



Figure 4.15: Balancing a metre rod on a wedge

Solution:

$w_1 = ?$

$w_2 = 10\text{ N}$

Moment arm of w_1 = OA = 25 cm = 0.25m

Moment arm of w_2 = OB = 40 cm = 0.40m

Applying principle of moments;

Clockwise moments = Anticlockwise moments

$\therefore$ moment of w_2 = moment of w_1

or $w_2 \times$moment arm of w_2 = $w_1 \times$moment arm of w_1

Thus $w_1 \times OA = w_2 \times OB$

or $w_1 \times 0.25\text{m} = 10\text{N} \times 0.40\text{m}$

or $$w_1 = \frac{10\text{N} \times 0.40\text{m}}{0.25\text{m}}$$

$w_1 = 16\text{ N}$

Thus, weight of the block suspended at point A is 16 N.

4.6 Centre of mass

Q.8. Define and explain the centre of mass.

Ans: Centre of mass of a system is such a point where an applied force causes the system to move without rotation.

Explanation:

It is observed that the centre of mass of a system moves as if its entire mass is confined at that point. A force applied at such a point in the body does not produce any torque in it i.e. the body moves in the direction of net force (F) without rotation.

Centre of mass can be understood by following cases.

Consider a system of two particles A and B connected by a light rigid rod as shown in figure.

Figure 4.16: Centre of mass of two unequal masses.

Let O is a point anywhere between A and B.

Case I:

Let a force is applied at point O. If the system moves in the direction of force F without rotation such as shown in figure, then point O is the centre of mass of the system.

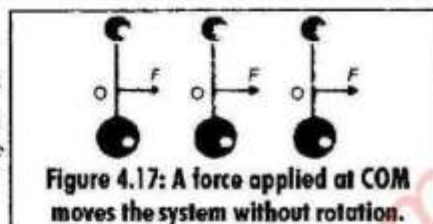



Figure 4.17: A force applied at COM moves the system without rotation.

Case II:

When the force is applied near the lighter particle, the system moves as well as rotates as shown in figure.

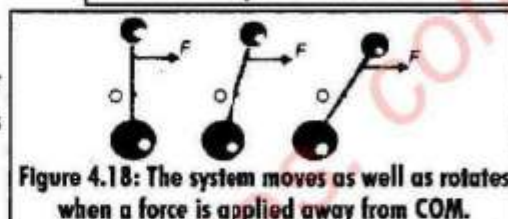



Figure 4.18: The system moves as well as rotates when a force is applied away from COM.

Case III:

When the external force acts near the heavier particle, the system moves as well as rotates as shown in figure.

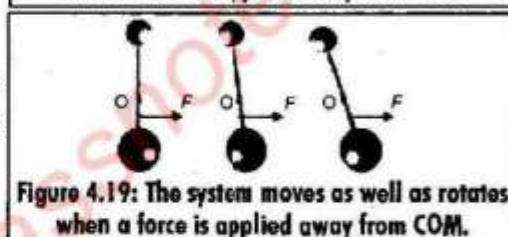



Figure 4.19: The system moves as well as rotates when a force is applied away from COM.

Q.9. Define and explain the centre of gravity.

Ans: Centre of gravity:

The centre of gravity of a body is defined as a point where the whole weight of the body appears to act vertically downward.

Explanation: A body is made up of a large number of particles as illustrated in given figure.

The pull of the Earth acting on a particle is equal to its weight. These forces acting on the particles of a body are almost parallel.

The resultant of all these parallel forces is a single force equal to weight of the body. A point where this resultant force acts vertically towards the centre of the Earth is called the centre of gravity G of the body.

Figure 4.20: Centre of gravity of a body is a point where its entire weight is assumed to act vertically downward.

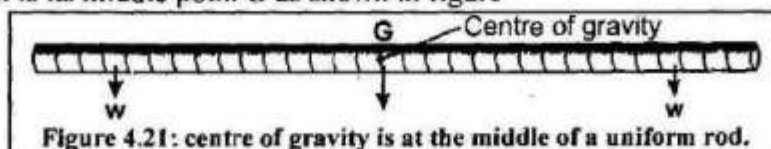
Use of centre of gravity: It is useful to know the location of the centre of gravity of a body in problems dealing with equilibrium.

Q.10. How centre of gravity of symmetrical shapes objects can be found? Give examples to justify the answer.

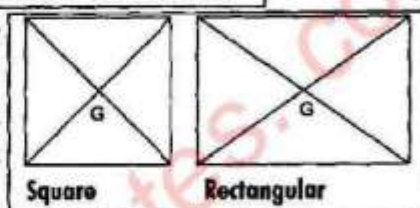
Ans: The centre of gravity of objects which have symmetrical shapes can be found from their geometry.

Example #1: Centre of gravity of uniform rod:

The centre of a gravity of a uniform rod lies at a point where it is balanced. This balance point is its middle point G as shown in figure

Figure 4.21: centre of gravity is at the middle of a uniform rod.

Example #2: (Centre of gravity of a square or a rectangular shape):

The centre of a gravity of a uniform square or a rectangular sheet is the point of intersection of its diagonals as shown in figure.

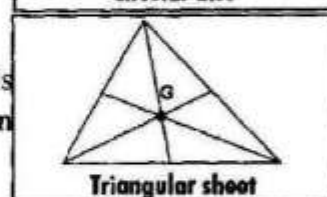
Square **Rectangular**

Example #3: (Centre of gravity of a circular disc):

The centre of a gravity of a uniform circular disc is as its centre as shown in figure.
Similarly, the centre of gravity of a solid sphere or hollow sphere is the centre of the spheres as shown in figure.

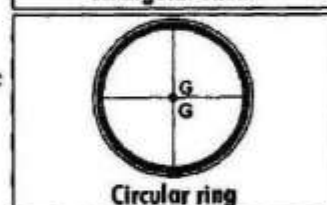
Circular disc

Example #4: Centre of gravity of a triangular sheet.

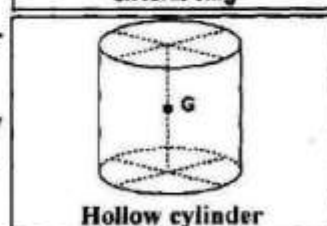
The centre of a gravity of a uniform triangular sheet is the point of intersection of its medians as shown in given figure.

Triangular sheet

Example #5: Centre of gravity of a circular ring

The centre of a gravity of a uniform circular ring is the centre of the ring as shown in the figure.

Circular ring

Example #6: Centre of gravity of a uniform solid or hollow cylinder.

The centre of a gravity of a uniform solid or hollow cylinder is the middle point on its axis as shown in the figure.

Hollow cylinder

Q.11. How will you find out the centre of gravity of an irregular shaped thin lamina? Explain.

Ans: A simple method to find the centre of gravity of a body is by the use of a plumb-line

Plumb-line:

A plumb-line consists of a small metal bob (lead or brass) supported by a string.

Explanation: In the apparatus of plumb line when the bob is suspended freely by the string, it rests along the vertical direction due to its weight acting vertically downward as shown in the given figure.

In this state, centre of gravity of the bob is exactly below its point of suspension.

Figure 4.23: (a) Plumbline (b) Locating the centre of gravity of a piece of cardboard by using plumbline

Experiment: By using the following procedure centre of gravity of any irregular shaped body can be found out.

1. Take a flat irregular piece of cardboard.
2. Make few holes A,B and C near its edge as shown in figure.
3. Fix a nail on a wall.
4. Support the cardboard on the nail through one of the holes (let it be A). So that the cardboard can swing freely about A. The cardboard will come to rest with its centre of gravity vertically below the nail.
5. Vertical line from A can be located by means of a plumbline hung from the nail. Mark a line on the cardboard behind the plumbline.
6. Repeat it by supporting the cardboard from hole B. The line from B will intersect at a point G.
7. Repeat it by supporting the cardboard from hole C. Check that this line also passes through G.

Conclusion: It will be found that all vertical lines from holes A, B and C have a common point G. This common point G is the **centre of gravity** of the cardboard.

4.7 Couple

Q.12. What is couple? Give examples. How total torque produced by the couple can be found out?

Ans: Couple: A couple is formed by two unlike parallel forces of the same magnitude but not along the same line.

Example # 1:

When a driver turns a vehicle, he applies forces that produce a torque. This torque turns the steering wheel. These forces act on opposite sides of the steering wheel as shown in figure. These forces are equal in magnitude but opposite in direction. These two forces form a couple.

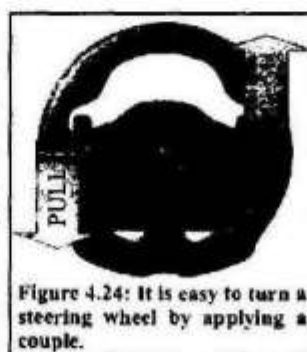
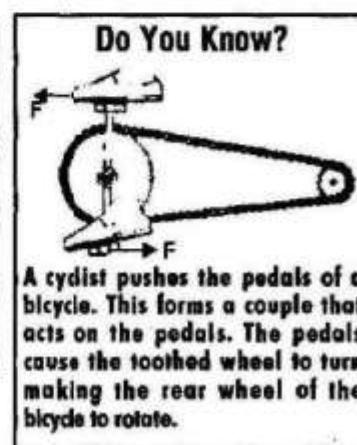



Figure 4.24: It is easy to turn a steering wheel by applying a couple.

Do You Know?

A cyclist pushes the pedals of a bicycle. This forms a couple that acts on the pedals. The pedals cause the toothed wheel to turn making the rear wheel of the bicycle to rotate.

Example # 2: A double arm spanner is used to open a nut. Equal forces each of magnitude F are applied on ends A and B of a spanner in opposite direction as shown in given figure.

These forces form a couple that turns the spanner about point O.

Directions of torque produced by the forces of couple:

The torques produced by both the forces of a couple have the same directions.

Figure 4.25: A double arm spanner

Total torque produced by the couple:

The total torque produced by the couple will be.

Total torque of the couple $= F\times OA + F\times OB$

$= F(OA + OB)$

Torque of the couple $= F\times AB$ ________ (1)

Equation (1) gives the torque produced by a couple of forces F and F separated by distance AB.

> The torque of the couple is given by the product of one of the two forces and the perpendicular distance between them.

4.8 Equilibrium

Q.13. What is equilibrium? Into how many types it is divided? Explain with examples.

Ans: Equilibrium:

A body is said to be in equilibrium if no net force acts on it.

Types of equilibrium:

Equilibrium has two types.

(1) Static equilibrium **(2)** Dynamic equilibrium

(1) Static equilibrium: A body is said to be in static equilibrium if no net force acts on it and it is present in rest state.

Newton's View: Newton's first law of motion tells us that a body continues its state of rest if no resultant or net force acts on it.

Example #1: A book lying on a table is an example of equilibrium. This equilibrium is static. The weight of the book acting downward is balanced by the upward reaction of the table.

Example # 2: A picture hanging on a wall is an example of equilibrium. This equilibrium is also static.

Figure 4.27: A wall hanging is in equilibrium

Example #3: Consider a log of wood of weight (w) supported by ropes as shown in figure. Here the (w) is balanced by the forces F_1 and F_2 pulling the log upward.

(2) Dynamic equilibrium: A body is said to be in dynamic equilibrium if not net force acts on it and it is present in the state of motion.

Newton's View: Newton's first law of motion tells us that a body continues its state of uniform motion in a straight line if no resultant or net force acts on its.

Example: In case of objects moving with uniform velocity. the resultant force acting on them is zero.

1. A car moving with uniform velocity on a levelled road.
2. An aeroplane flying in the air with uniform velocity.

Figure 4.26: The forces acting on the log are; upward forces F_1, F_2 and its weight w in the downward direction.

A body in equilibrium thus remains at rest or moves with uniform velocity.

Q.14. How many conditions a body has to be in equilibrium. Define and explain the 1st condition of equilibrium.

Ans: There are two conditions for a body to be in equilibrium.

(i) First condition of equilibrium **(ii)** Second condition of equilibrium

(i) First condition of equilibrium: A body is said to satisfy first condition for equilibrium if the resultant of all the forces acting on it is zero.

Explanation:

Let n number of forces F_1, F_2, F_3, ... F_n are acting on a body such that

$$F_1 + F_2 + F_3 + ... + F_n = 0$$

or $\Sigma \mathbf{F} = 0$ ________ (1)

Equation (1) is called the first condition of equilibrium.

Sigma (Σ): The symbol (Σ) is a Greek letter called sigma used for summation.

Alternative method to represent the 1st condition of equilibrium:

The first condition of equilibrium can also be stated in terms of x and y-components of the forces acting on the body as.

$$F_{1x} + F_{2x} + F_{3x} + ... + F_{nx} = 0$$

and $F_{1y} + F_{2y} + F_{3y} + ... + F_{ny} = 0$

OR $\Sigma F_x = 0$ and $\Sigma F_y = 0$

Example #1: A book lying on a table or a picture hanging on a wall, are at rest and satisfy first condition of equilibrium.

Example #2: A paratrooper coming down with terminal velocity (constant velocity) also satisfies first condition for equilibrium and is thus in equilibrium.

Figure 4.28: A paratrooper coming down with terminal velocity is in equilibrium

Example 4.5 ***A block of weight 10 N is hanging through a cord as shown in figure. Find the tension in the cord.***

Solution: Weight of the block w = 10 N

Tension in the cord T = ?

Applying first condition of equilibrium

$$\Sigma F_x = 0$$

There is no force acting along x-axis.

$$\Sigma F_y = 0$$

$\therefore$ $T - w = 0$

or $T = w$

or $T = 10\text{ N}$

Thus, the tension in the cord is 10 N.

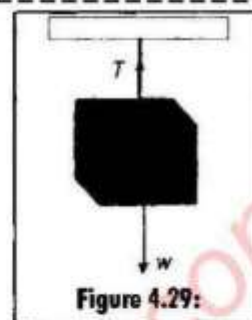



Figure 4.29:

Q.15. Define and explain the second condition of equilibrium.

Ans: Second condition of equilibrium: A body satisfies second condition of equilibrium when the resultant torque acting on it is zero.

Formula: Mathematically, second condition of equilibrium can be written as;

$$\Sigma\tau = 0$$

Explanation: First condition for equilibrium does not ensure that a body is in equilibrium. This is clear from the following example.

Example:

☆ Consider a body pulled by the forces F_1 and F_2 as shown in figure (a).
The two forces are equal but opposite to each other.
Both are acting along the same line, hence their resultant will be zero.
According to first condition, the body will be in equilibrium.

Figure 4.30: (a) Two equal and opposite forces acting along the same lines

☆ Now shift the location of the forces as shown in figure (b).

In this situation, the body is not in equilibrium although the first condition for equilibrium is still satisfied. It is because the body has the tendency to rotate. This situation demands another condition for equilibrium in addition to the first condition of equilibrium. This is called second condition of equilibrium.

Figure 4.30: (b) Two equal and opposite forces acting along different lines.

QUICK QUIZ:

1. **A ladder leaning at a wall as shown in figure is in equilibrium. How?**

Ans: A ladder leaning at a wall is in equilibrium. Because the weight of the ladder produces an anticlockwise torque. The wall pushes the ladder at its top end thus produces a clockwise torque. Anticlockwise and clockwise torque will cancel the effect of each other.

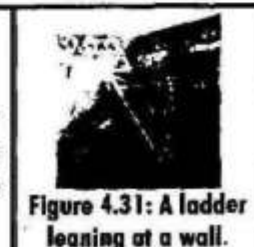



Figure 4.31: A ladder leaning at a wall.

2. The weight of the ladder in figure produces an anticlockwise torque. The wall pushes the ladder at its top end thus produces a clockwise torque. Does the ladder satisfies second condition for equilibrium?

Ans: Yes the ladder satisfies second condition for equilibrium because the clockwise torque will cancel the effect of anticlockwise torque. So the resultant torque acting in this situation is zero.

3. Does the speed of a ceiling fan go on increasing all the time.

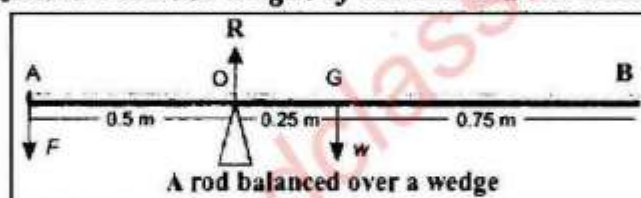
Ans: No the speed of a ceiling fan does not go on increasing all the time. It remains at constant speed.

4. Does the fan satisfy second condition for equilibrium when rotating with uniform speed?

Ans: Yes a rotating ceiling fan satisfy second condition for equilibrium. Because a ceiling fan rotating at constant speed is in equilibrium as net torque acting on it is zero.

Figure 4.32: A ceiling fan rotating at constant speed is in equilibrium as net torque acting on it is zero.

Example 4.6 ***A uniform rod of length 1.5m is placed over a wedge at 0.5m from its one end. A force of 100N is applied at one of its ends near the wedge to keep it horizontal. Find the weight of the rod and the reaction of the wedge.***

A rod balanced over a wedge

Solution:

$$F = 100\text{ N}$$
$$OA = 0.5\text{ m}$$
$$AG = BG = 0.75\text{m}$$
$$OG = AG - AO = 0.75\text{m} - 0.5\text{m} = 0.25\text{ m}$$
$$w = ?$$
$$R = ?$$

Applying second condition for equilibrium, taking torques about O.

$$\Sigma_\tau = 0$$
$$F\times AO + R\times 0 - w\times OG = 0$$
$$100\text{N}\times 0.5\text{m} - w\times 0.25\text{ m} = 0$$
or
$$w\times 0.25\text{m} = 100\text{ N}\times 0.5\text{m}$$
$$w = \frac{100\text{N}\times 0.5\text{m}}{0.25\text{m}}$$
$$w = 200\text{ N}$$

Applying first condition for equilibrium

$$\Sigma F_y = 0$$
$$R - F - w = 0$$

$R - 100\ N - 200\ N = 0$

or $R = 300\ N$

Thus, weight of the rod is 200N and reaction of the wedge is 300N.

Q.16.There are how many states of equilibrium. Define and explain them with examples.

Ans: There are three states of equilibrium.

(1) Stable equilibrium
(2) Unstable equilibrium
(3) Neutral equilibrium

Can you do this without falling?

(1) Stable equilibrium:

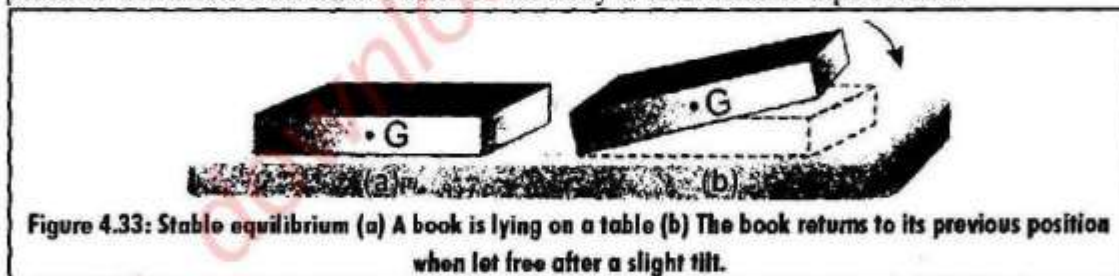
A body is said to be in stable equilibrium if after a slight tilt it returns to its previous position.

Relation of centre of gravity with stable equilibrium:

When a body is in stable equilibrium, its centre of gravity is at the lowest position. When it is tilted, its centre of gravity rises. It returns to its stable state by lowering its centre of gravity. A body remains in stable equilibrium as long as the centre of gravity acts through the base of the body.

Example #1:

Consider a book lying on the table. Tilt the book slightly about its one edge by lifting it from the opposite side as shown in the given figure. It returns to its previous position when sets free. Such a state of the body is called stable equilibrium.

Figure 4.33: Stable equilibrium (a) A book is lying on a table (b) The book returns to its previous position when let free after a slight tilt.

Example # 2: A vehicle is made heavy at its bottom to keep its centre of gravity as low as possible. A lower centre of gravity keeps it stable. The base of a vehicle is made wide so that the vertical line passing through its centre of gravity should not get out of its base during a turn.

Explantion: Consider a block as shown in figure.

☆ When the block is tilted, its centre of gravity (G) rises. If the vertical line through G passes through its base in the tilted position as shown in figure (b).
The block returns to its previous position.

☆ If the vertical line through G gets out of its base as shown in figure (c).

The block does not return to its previous position. It topples over its base and moves to new stable equilibrium position.

Figure 4.34: (a) Block in stable equilibrium (b) Slightly tilted block is returning to its previous position. (c) A more tilted block topples over its base and does not return to its previous position.

(2) Unstable equilibrium:

If a body does not return to its previous position when sets free after a slightest tilt is said to be in unstable equilibrium.

Figure 4.35: A double decker bus being under test for stability.

Relation of unstable equilibrium with centre of gravity:

The centre of gravity of the body is at its highest position in the state of unstable equilibrium. As the body topples over about its base (tip), its centre of gravity moves towards its lower position and does not return to its previous position.

Example:

Take a pencil and try to keep it in the vertical position on its tip as shown in the given figure (4.36).

Whenever this pencil is left, it topples over about its tip and falls down. This is called unstable equilibrium. In unstable equilibrium, a body may be made to stay only for a moment. Thus a body is unable to keep itself in the state of unstable equilibrium.

Figure 4.36: Unstable equilibrium (a) Pencil just balanced at its tip with centre of gravity G at the highest position. (b) Pencil topples over caused by the torque of its weight acting at G.

(3) Neutral equilibrium:

If a body remains in its new position when disturbed from its previous position, it is said to be in a state of neutral equilibrium.

Relation of centre of gravity with neutral equilibrium:

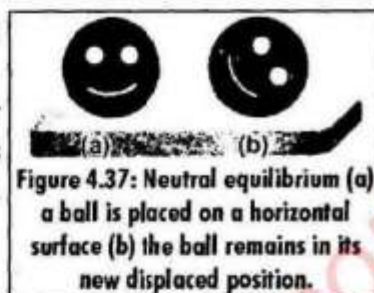
In neutral equilibrium the centre of gravity of the body remains at the same height, irrespective to its new position.

Example: Take a ball and place it on a horizontal surface as shown in given figure.

Roll the ball over the surface and leave it after displacing it from its previous position. It remains in its new position and does not return to its previous position. This is called neutral equilibrium.

(a) (b)
Figure 4.37: Neutral equilibrium (a) a ball is placed on a horizontal surface (b) the ball remains in its new displaced position.

Some more examples of neutral equilibrium:

There are various objects which have neutral equilibrium such as, a sphere, a roller, a pencil lying horizontally, an egg lying horizontally on a flat surface etc.

4.9 Stability and Position of centre of mass

Q.17. How stability relates with the centre of mass? Give examples.

Ans: The position of centre of mass of an object plays an important role in their stability.

Low position of centre of gravity: To make the objects stable, their centre of mass must be kept as low as possible.

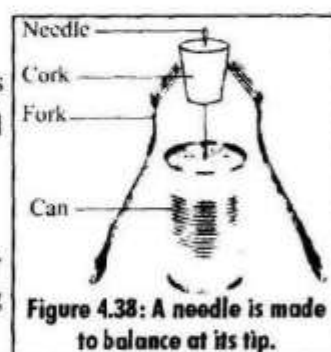
Example # 1: For the maximum stability, racing cars are made heavy at the bottom and their height is kept to be minimum.

Example # 2:

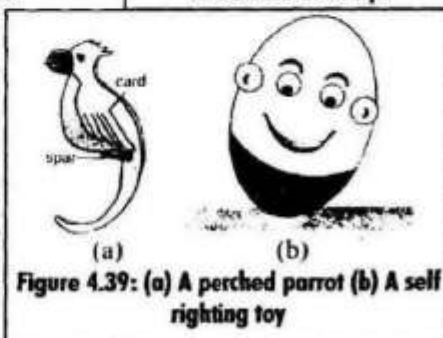
Circus artists such as tight rope walkers use long poles to lower their centre of mass. In this way they are prevented from topple over.

Example # 3:

The given figure shows a sewing needle fixed in a cork. The cork is balanced on the tip of the needle by hanging forks. The forks lower the centre of mass of a system.

Figure 4.38: A needle is made to balance at its tip.

Example # 4: The given figure (a) shows a perched parrot which is made heavy at its tail for the maximum stability.

Example # 5: The given figure (b) shows a toy that keeps itself upright when tilted. It has a heavy semi-spherical base. When it is tilted, its centre of mass rises. It returns to its upright position at which its centre of mass is at the lowest.

Figure 4.39: (a) A perched parrot (b) A self righting toy

Above all objects return to their stable states when disturbed.

In each case the centre of mass is vertically below their point of support. This makes their equilibrium stable.

SUMMARY

- Parallel forces have their lines of action parallel to each other.
- If the direction of parallel forces is the same, they are called like parallel forces. If two parallel forces are in opposite direction to each other, then they are called unlike parallel forces.
- The sum of two or more forces is called the resultant force.
- A graphical method used to find the resultant of two or more forces is called the head to tail rule.
- Splitting up a force into two mutually perpendicular components is called the resolution of that force. These components are
$$F_x = F\cos\theta, F_y = F\sin\theta$$
- A force can be determined from its perpendicular components as $F = \sqrt{F_x^2 + F_y^2}$, $\theta = \tan^{-1}\frac{F_y}{F_x}$
- Torque or moment of a force is the turning effect of the force. Torque of a force is equal to the product of force and moment arm of the force.
- According to the principle of moments, the sum of clock-wise moments acting on a body in equilibrium is equal to sum of anticlockwise moments acting on it.
- Centre of mass of a body is such a point where a net force causes it to move without rotation.
- The centre of gravity of a body is a point where the whole weight of a body acts vertically downward.
- A couple is formed by two parallel forces of the same magnitude but opposite in direction.
- A body is in equilibrium if net force acting on it is zero. A body in equilibrium either remains at rest or moves with a uniform velocity.
- A body is said to satisfy second condition for equilibrium if the resultant torque acting on it is zero.
- A body is said to be in the stable equilibrium if after a slight tilt it returns to its previous position.
- If a body does not return to its previous position when sets free after slightly tilt is said to be in unstable equilibrium.
- A body that remains in its new position when disturbed from its previous position is said to be in a state of neutral equilibrium.

SOLVED QUESTIONS

4.1 Encircle the correct answers from the given choices.

(i) Two equal but unlike parallel forces having different line of action produce:
(a) a torque (b) a couple (c) equilibrium (d) neutral equilibrium

(ii) The number of forces that can be added by head to tail rule are:
(a) 2 (b) 3 (c) 4 (d) Any number

(iii) The number of perpendicular components of a force are:
(a) 1 (b) 2 (c) 3 (d) 4

(iv) A force of 10 N is making an angle of 30° with the horizontal. Its horizontal component will be:
(a) 4 N (b) 5 N (c) 7 N (d) 8.7 N

(v) A couple is formed by:
(a) two forces perpendicular to each other (b) two like parallel forces
(c) two equal and opposite forces in the same line
(d) two equal and opposite forces not in the same line

(vi) A body is in equilibrium when its:
(a) acceleration is uniform (b) speed is uniform
(c) speed and acceleration are uniform (d) acceleration is zero

(vii) A body is in neutral equilibrium when its centre of gravity:
(a) is at its highest position (b) is at the lowest position
(c) keeps its height if displaced (d) is situated at its bottom

(viii) Racing cars are made stable by:
(a) increasing their speed (b) decreasing their mass
(c) lowering their centre of gravity (d) decreasing their width

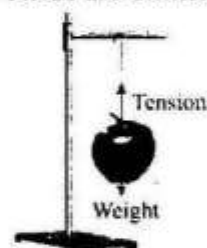
Ans: **(i)** a couple **(ii)** any number **(iii)** 2 **(iv)** 8.7 N
(v) two equal and opposite forces not in the same line **(vi)** acceleration is zero
(vii) keeps its height if displaced **(viii)** lowering their centre of gravity

4.2 Define the following:

(i) Resultant vector **(ii) Torque**
(iii) Centre of mass **(iv) Centre of gravity**

(i) Resultant vector: A resultant vector is a single vector that has the same effect as the combined effect of all the vectors to be added.

(ii) Torque: The turning effect of a force is called torque or moment of the force. It is determined by the product of force F and its moment arm L. It is denoted as τ. In SI units, the unit of torque is Newton-meter (Nm).

(iii) Centre of mass: Centre of mass of a system is such a point where an applied force causes the system to move without rotation.

(iv) Centre of gravity: The centre of gravity of a body is defined as a point where the whole weight of the body appears to act vertically downward.

4.3. Differentiate the following:

(i) Like and unlike forces **(ii) Torque and couple**

(iii) Stable and neutral equilibrium

(i) Like and unlike forces:

Like Forces	*Unlike Forces*
i. Like forces are also called like parallel force	i. Unlike forces are also called unlike parallel forces.
ii. Like force are the forces that have the same direction to each other.	ii. Unlike forces are the forces that are in the opposite direction to each other.
iii. A bag has a large number of apples in it, the weight of all the apples is acted vertically downward so these all forces are in same direction, called like forces. Figure: Like parallel forces	iii. An apple is suspended by a string. The string is stretched by the weight of apple. Weight is acted downward but tension in the string is actede in upward direction. These are unlike forces. Figure: Unlike parallel forces along the same line

(ii) Torque and couple:

Torque	*Couple*
i. The turning effect of a force is called torque or moment of force	i. A couple is formed by two unlike parallel forces of the same magnitude but not along the same line.
ii. To produce a torque we need only one force atleast.	ii. To produce a couple we need two unlike parallel forces atleast.
iii. The torque is produced by a force F and the moment arm.	iii. Torque of the couple = F×AB in this F represents force and AB represents the distance between two forces. The torque produced by a couple force F and F separated by the total distance (AB), that is the couple arm.
iv. Torque by a force is the product of force F and its moment arm.	iv. The torque of a couple is given by the product of one of the two forces and the perpendicular distance between them.

(iii) Stable and neutral equilibrium:

Stable equilibrium	*Neutral equilibrium*
i. A body is said to be in stable equilibrium if after a slight tilt it returns to its previous position.	**i.** If a body remains in its new position when disturbed from its previous, it is said to be in a state of neutral equilibrium.
ii. When a body is in stable equilibrium, its centre of gravity is at the lowest position. When it is tilted, its centre of gravity rises. It returns to its stable state by lowering its centre of gravity.	**ii.** In neutral equilibrium, the centre of gravity of the body remains at the same height, irrespective to its new position.
iii. A book placed on the table horizontally is an example of stable equilibrium.	**iii.** The rolling ball is an example of neutral equilibrium.

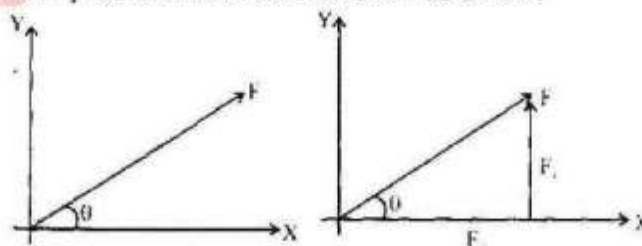
4.4 How head to tail rule helps to find the resultant of forces?

Head to tail rule is a graphical method of vector addition. In this method according to a selected scale we draw all the forces according to their magnitude. Take any force as a first vector and the second force starts from the head of first vector by starting it with a tail so that tail of second vector coincides with the head of first vector. Similarly, draw all the forces.

Such that head of previous vector coincides with the tail of next vector. By drawing all the vectors in this manner, draw a resultant force, which starts from the tail of first force and its head coincides with the head of last force.

4.5 How can a force be resolved into its perpendicular components?

To resolve a force into its rectangular component, draw the resultant force according to its magnitude on the selected scale and required direction.

Then draw a perpendicular from the head of this resultant force to the x-axis and by joining make the y-component of the resultant force as below.

The F_y is the y-component of that vector and can be found as:

$$F_y = F \sin\theta$$

and F_x is the x-component of that vector and can be found as:

$$F_x = F \cos\theta$$

4.6 When is a body said to be in equilibrium?

A body is said to be in equilibrium if it follows both conditions of equilibrium.

A body is in equilibrium if net force acting on it is zero, and a body is said to be in equilibrium if the resultant torque acting on it is zero.

$$\Sigma F = 0, \text{ or } \Sigma F_y = 0,\ \Sigma F_x = 0$$
$$\Sigma \tau = 0$$

4.7 Explain the first condition for equilibrium.

The body is said to satisfy first condition for equilibrium if the resultant of all the forces acting on it is zero. Let 'n' number of forces $F_1, F_2, F_3, \ldots\ldots\ldots\ F_n$ are acting on a body such that

$$F_1 + F_2 + F_3 + \ldots\ldots\ldots + F_n = 0$$

or $\quad \Sigma F_n = 0$

The symbol Σ is a Greek letter called sigma used for summation.

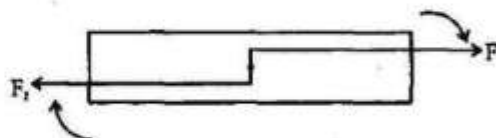
The first condition for equilibrium can also be stated in terms of x and y-components of the forces acting on the body as:

$$F_{1x} + F_{2x} + F_{3x} + \ldots\ldots\ldots + F_{nx} = 0$$

and $\quad F_{1y} + F_{2y} + F_{3y} + \ldots\ldots\ldots + F_{ny} = 0$

or $\quad \Sigma F_x = 0 \quad$ and $\quad \Sigma F_y = 0$

4.8 Why is there a need of second condition for equilibrium if a body satisfies first condition for equilibrium?

The first condition for equilibrium does not ensure that a body is in equilibrium. Consider a body pulled by the forces F_1 and F_2, the two forces are equal but opposite to each other. These forces are not acted along the same line as given in figure.

The first condition of equilibrium is although satisfied but the body has tendency to rotate. This situation demands another condition for equilibrium that is the second condition of equilibrium, a body satisfies second condition of equilibrium when the resultant torque acting on it zero. $\Sigma \tau = 0$

4.9 What is second condition for equilibrium?

According to the second condition for equilibrium, a body satisfies second condition for equilibrium when the resultant torque acting on it is zero. Mathematically; $\Sigma \tau = 0$

4.10 Give an example of a moving body which is in equilibrium.

A paratrooper coming down with terminal velocity (constant velocity) is in equilibrium as all the forces acting on it is equal to zero, which satisfies the first condition of equilibrium.

4.11 Think of a body which is at rest but not in equilibrium.

There is not a single body in the universe which is at rest but not in equilibrium.

4.12 Why cannot a body be in equilibrium due to single force acting on it?

For a body is said to be in equilibrium it is necessary that the net force acting on a body is zero and the sum of all the torques acting on a body is zero. These two conditions can not be satisfied if there is one force only. Because there is not any other force which nullify the effect of this force to keep the body in equilibrium and hence, this single force tends to move or rotate the body according to its point of application. So, if a single force is applied on a body, it could not be in equilibrium i.e

$$\Sigma F \neq 0$$
$$\Sigma \tau \neq 0$$

4.13 Why the height of vehicles is kept as low as possible?

Vehicles are made heavy at the bottom and their height is kept to be minimum. This lowers their centre of gravity and helps to increase their stability. Because to make them stable, their centre of mass must be kept as low as possible. Therefore, height of vehicles is kept as low as possible.

4.14 Explain what is meant by stable, unstable and neutral equilibrium. Give one example in each case.

Stable equilibrium: A body is said to be in stable equilibrium if after a slight tilt it returns to its previous position. When a body is in stable equilibrium; its centre of gravity is at the lowest position. When it is tilted, its centre of gravity rises. Body returns to its stable state by lowering its centre of gravity.

For example: A vehicle is made heavy at its bottom to keep its centre of gravity as low as possible. A lower centre of gravity keeps it stable.

Unstable equilibrium: If a body does not return to its previous position when sets free after a slightest tilt is said to be in unstable equilibrium.

The centre of gravity of the body is at its heighest position in the state of unstable equilibrium.

For example: Take a pencil and try to keep it in the vertical position on its tip. Whenever we leave it, the pencil topples over about its tip and falls down. In unstable equilibrium, a body may be made to stay only for a moment.

Neutral equilibrium: If a body remains in its new position when disturbed from its previous position, it is said to be in a state of neutral equilibrium.

In neutral state of equilibrium the centre of gravity of the body remains at the same height, irrespective to its new position.

For example: When we roll a ball on a horizontal surface and leave it after displacing it from its previous position. It remains in its new position and does not return to its previous position.

SOLVED PROBLEMS

4.1 Find the resultant of the following forces:
(i) 10 N along x-axis (ii) 6 N along y-axis and
(iii) 4 N along negative x-axis

Data: Force 1 $= F_1 = 10N$ along x–axis
Force 2 $= F_2 = 6N$ along y–axis
Force 3 $= F_3 = 4N$ along negative x–axis

Required: (a) Find the resultant of all the above forces $= F = ?$
(b) direction $= \theta = ?$

Formulas: By using the following equations;

$$F = \sqrt{F_x^2 + F_y^2}$$

and $$\theta = \tan^{-1}\left(\frac{F_y}{F_x}\right)$$

Solution: As we know that in x-direction two forces are acted. So, first find the resultant of them:

$$F_x = 10N - 4\,N = 6\,N$$
$$F_x = 6\,N \quad \therefore \text{[4N along negative x-axis]}$$
$$F_y = 6\,N$$

Now by using the relation;

$$F = \sqrt{F_x^2 + F_y^2}$$

By putting values, we get.

$$F = \sqrt{6^2 + 6^2}$$
$$F = \sqrt{36 + 36}$$
$$F = \sqrt{72}$$
$$\boxed{F = 8.5N}$$

Now; $$\theta = \tan^{-1}\left(\frac{F_y}{F_x}\right)$$

By putting values, we get

direction $= \theta = \tan^{-1}\left(\frac{6}{6}\right)$

direction $= \theta = \tan^{-1}(1)$

$$\boxed{\theta = 45^\circ}$$

Answer: Hence the resultant force is **8.5 N** making **45°** with x-axis.

4.2 Find the perpendicular components of a force of 50 N making an angle of 30° with x-axis.

Data: Magnitude of resultant force = F = 50 N
Angle made by resultant force with x-axis = θ = 30°

Required: Find the rectangular components of a force F.

F_x = x-component of the force = ?
F_y = y-component of the force = ?

Formulas: As we know that;

$F_x = F\cos\theta$
and $F_y = F\sin\theta$

Solution: From the figure.

The resultant of horizontal and vertical components is:

$F = 50\text{ N}$

x-component of the force:

$F_x = F\cos\theta$

By putting values; we get

$F_x = 50\cos(30°)$ ∴ $\theta = 30°$

$F_x = 50 \times 0.866$

$\boxed{F_x = 43.4\text{N}}$

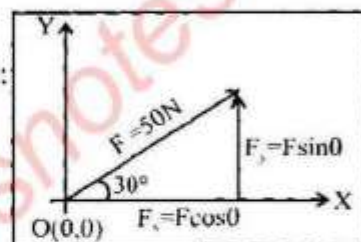
y-component of the force:

$F_y = F\sin\theta$

By putting the values in this equation, we get:

$F_y = 50\sin(30°)$

$F_y = 50 \times 0.5$

$\boxed{F_y = 25\text{ N}}$

Answers: Hence the rectangular components of the force;

x-component = F_x = 43.3 N
y-component = F_y = 25 N

4.3 Find the magnitude and direction of a force, if its x-component is 12 N and y-component is 5N.

Data: x-component of the force = F_x = 12 N
y-component of the force = F_y = 5 N

Required: (a) Find the magnitude of the resultant force = F = ?
(b) Find the direction of the resultant force = θ = ?

Formulas: By using the basic relation of the resultant vector from its rectangular

components, we get

(a) $F = \sqrt{F_x^2 + F_y^2}$

(b) $\theta = \tan^{-1}\left(\frac{F_y}{F_x}\right)$

Solution: As we know the relation, to find the magnitude of a resultant vector:

$$F = \sqrt{F_x^2 + F_y^2}$$

By putting values in the above equation, we get

$$F = \sqrt{(12)^2 + (5)^2}$$

$$F = \sqrt{144 + 25} = \sqrt{169}$$

$$\boxed{F = 13\,N}$$

(b) By using the following relation we can find the direction of resultant froce;

$$\theta = \tan^{-1}\left(\frac{F_y}{F_x}\right)$$

By putting the values; we get:

$$\theta = \tan^{-1}\left(\frac{5}{12}\right)$$

$$\theta = \tan^{-1}(0.417)$$

Answers: $\boxed{\theta = 22.6^\circ \text{ with x-axis}}$

(a) The magnitude of the resultant force $= F = 13\ N$

(b) The angle of the resultant force with x-axis $= \theta = 22.6^\circ$

4.4 A force of 100N is applied perpendicularly on a spanner at a distance of 10cm from a nut. Find the torque produced by the force.

Data: Magnitude of Force = $F = 100\ N$

Force applied perpendicular to the spanner = $\theta = 90^\circ$

Moment arm = $L = 10\ cm = 10 \times 10^{-2}\ m$

Required: Find the torque produced by the force = $\tau = ?$

Formula: By using the basic relation;

$$\text{torque} = \text{Force} \times \text{moment arm} \times \sin\theta$$

$$\tau = F \times L \times \sin\theta$$

Solution: By using the above relation

$$\tau = F\,L\,\sin\theta$$

By substituting the values in above equation;

$$\tau = (100)\,(0.1)\sin 90^\circ$$

$\tau = (10)(1)$ $\therefore \sin 90° = 1$

$\boxed{\tau = 10\text{Nm}}$

Answer: The torque produced by the force = τ = 10 Nm

4.5 A force is acting on a body making an angle of 30° with the horizontal. The horizontal component of the force is 20 N. Find the force.

Data: Horizontal component of the force = F_x = 20 N

The force acting on a body making an angle with the horizontal = θ = 30°

Required: force = F = ?

Formula: By using the basic relation of rectangular component as

$F_x = F\cos\theta$

Solution: As we know that, x-component of the force is given as;

$F_x = F\cos\theta$

By rearranging the equation;

$$F = \frac{F_x}{\cos\theta}$$

By substituting the values in above equation;

$$F = \frac{20}{\cos(30°)} \qquad \therefore \theta = 30°$$

$$F = \frac{20}{0.866} \qquad \boxed{F = 23.1\text{N}}$$

Answer: The magnitude of the resultant force F = 23.1 N

4.6 The steering of a car has a radius 16 cm. Find the torque produced by a couple of 50 N.

Data: The steering of a car has a radius = r = 16cm = 0.16m

The force acting on the steering = F = 50 N

Required: Find the torque produced by a couple = τ = ?

Formula: By using the following relation:

Torque of the couple = force × perpendicular distance between them

Let the perpendicular distance = diameter of the steering

= 2r

Torque of the couple = F × 2r

Solution: By using the given relation,

Torque of the couple = F × 2r .... (I)

By putting values in the above equation I, we get.

Torque of the couple = (50) (2 × 0.16)

Torque of the couple = (50) (0.32)

$\boxed{\tau = \text{torque of the couple} = 16\text{ Nm}}$

Answer: The required torque of the couple τ = 16 Nm

4.7 A picture frame is hanging by two vertical strings. The tensions in the strings are 3.8 N and 4.4 N. Find the weight of the picture frame.

Data: A picture frame is hanging by two vertical strings,

The tension in one string $= T_1 = 3.8\ N$

The tension in the second string $= T_2 = 4.4\ N$

Required: Find the weight of the picture frame $= w = ?$

Formula: By using the first condition of equilibrium;

$$\Sigma F = 0$$

Solution: As we know the equation of first condition of equilibrium; $\Sigma F = 0$
or we can write it as

$$\Sigma F_x = 0$$
$$\Sigma F_y = 0$$

Since there is no force acting in the horizontal direction so,

$\Sigma F_x = 0$ (satisfied)

Now for the force acting along the y-direction;

$$\Sigma F_y = 0$$
$$T_1 + T_2 + w = 0$$

By putting values; we get.

$$-3.8 - 4.4 + w = 0$$
$$-8.2 + w = 0$$
$$\boxed{w = +8.2}$$

Answer: The weight of the picture frame = w = 8.2 N

4.8 Two blocks of masses 5 kg and 3 kg are suspended by the two strings as shown. Find the tension in each string.

Data: The mass of one block $= m_1 = 5kg$

The mass of the second block $= m_2 = 3\ kg$

Both masses are suspended by two strings:

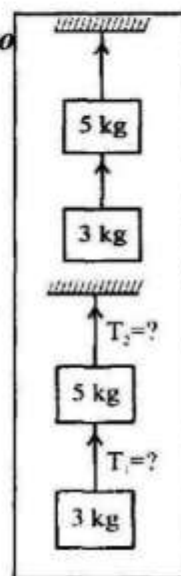
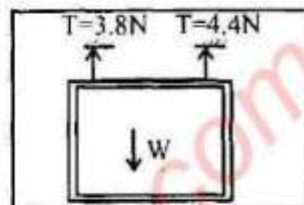
Required: Find the tension in each string $= T = ?$

Means: (a) Tension in one string $= T_1 = ?$

(b) Tension in other string $= T_2 = ?$

Formula: We can use the basic relation of the equilibrium:

$$\Sigma F_y = 0$$

or tension in string = weight of the body

$T = w$

and $w = mg$

Solution: For finding tension T_1, we can use the equation

$w = T_1$ .... (I)

and we know that $w = mg$

put in equation I $mg = T_1$

By putting values , we get

$T_1 = (3)(10)$

$\boxed{T_1 = 30N}$

As for finding the tension T_2 in the upper string, the total weight is contributed so, the weight for this part of string is

$w = mg$

$w = (m_1 + m_2)g$

$w = (3 + 5)(10)$

$w = 8 \times 10$

$\boxed{w = 80N}$

and as we know that;

Tension = weight

$T_2 = w$

$\boxed{T_2 = 80N}$

Answers: The tension in one string = $T_1 = 30$ N

The tension in second string = $T_2 = 80$ N

4.9 A nut has been tightened by a force of 200 N using 10 cm long spanner. What length of a spanner is required to loosen the same nut with 150 N force?

Data: The force applied to tight a nut = 200 N = F_1

Moment arm or the lenght of spanner = L_1 = 10 cm

The new force applied to lose the nut = F_2 = 150 N

Required: Length of a spanner is required to loosen the same nut = L_2 = ?

Formula: As we know that by providing condition

$\tau = F \times L$

Solution: By using the above equation of torque

$\tau_1 = F_1 \times L_1$

By putting values; we get.

$\tau_1 = (200)(10)$

$\tau_1 = 2000\ \text{Ncm} = \frac{2000}{100} = 20$

$\boxed{\tau_1 = 20\text{Nm}}$

Now according to the providing condition,

$\tau_1 = \tau_2 = F_2 \times L_2$

By putting values , we get

$20 = 150 \times L_2$

By rearranging the equation;

$L_2 = \frac{20}{150}$

or $L_2 = 0.133\ \text{m} = 0.133 \times 100 = 13.3$

$\boxed{L_2 = 13.3\text{cm}}$

Answer:

Hence the required new length of the spanner to open the same nut = L_2 = 13.3cm

4.10 A block of mass 10 kg is suspended at a distance of 20 cm from the centre of a uniform bar 1 m long. What force is required to balance it at its centre of gravity by applying the force at the other end of the bar?

Data: The mass of the block = m = 10 kg

distance of the block from the center of a bar = L_1 = 20 cm = 0.2 m

The total length of the uniform bar = L = 1 m

Required: force is required to balance the bar at its centre of gravity by applying the force at the other end of the bar = F_2 = ?

Formula: By using the second condition of equilibrium that is $\Sigma\tau = 0$

Solution: As we know that, according to the second condition of equilibrium, $\Sigma\tau = 0$

From figure, we can see that

$\tau_1 + \tau_2 = 0$

or; $-F_1 \times L_1 + F_2 \times L_2 = 0$

$\because \quad \tau = F \times L$

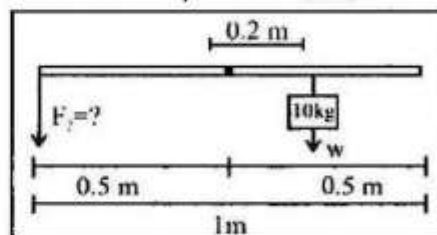
By rearranging the equation; we get

$F_2 \times L_2 = F_1 \times L_1$

$F_2 = \frac{F_1 L_1}{L_2}$ ________ (1)

By substituting the values;

as $F_1 = w = mg$

$F_1 = w = (10)(10)$

$$F_1 = 100\ N$$

By putting the value of force, in equation (I)

$$F_2 = \frac{(100)(0.2)}{0.5}$$

$$F_2 = \frac{20}{0.5}$$

$$\boxed{F_2 = 40N}$$

Answer: Hence the force required to balance the bar = $F_2 = 40\ N$

OBJECTIVE TYPE QUESTIONS (MCQ'S+SHORT ANSWER) FROM PREVIOUS ANNUAL PAPERS OF ALL SECONDARY BOARDS (LAHORE, GUJRANWALA, FAISALABAD, MULTAN, SAHIWAL, SARGODHA, RAWALPINDI, D.G. KHAN And BAHAWALPUR)

4.1+4.2	Like and Unlike Parallel Forces+Addition of Forces
4.3+4.4	Resolution of Forces+Torque or moment of a force
4.5	Principle of moments

☆ **Tick the correct answer.**

1. **Two equal but unlike parallel forces having different line of action produce:** **(RWP. GI, DGK. GII)**
   (A) a torque (B) a couple (C) equilibrium (D) neutral equilibrium
2. **The forces that are parallel to each other and have the same direction are called:** **(DGK. GI)**
   (A) Like parallel forces (B) Unlike parallel force
   (C) Resultant forces (D) Net parallel forces
3. **The resultant of all the forces acting on a body is called:** **(MLN. GII)**
   (A) Force (B) Friction Force (C) Net force (D) Gravitational force
4. **The number of vectors that can be added by head to tail rule are:** **(SWL. GI & GII, BWP. GII, LHR. GII)**
   (A) 2 (B) 3 (C) 4 (D) any number
5. **If $F_y = 4N$, $F_x = 3N$ what is magnitude of resultant force?** **(LHR. GI)**
   (A) 7 N (B) 5 N (C) 12 N (D) 10 N
6. **Complete equation $\frac{F_y}{F_x}$ = ______:** **(GRW. GI)**
   (A) sin θ (B) cos θ (C) tan θ (D) cosec θ

7. **The value of tan 45° is __________:** (GRW. GII)
(A) 0.5 (B) 1.732 (C) 0.577 (D) 1

8. **The number of perpendicular components of a force is:** (GRW. GII, FBD. GII, SGD. GII, DGK. GII)
(A) 4 (B) 3 (C) 2 (D) 1

9. **A force of 10 N is making an angle of 30° with x-axis. Its horizontal component will be:** (FBD. GII, DGK. GI, RWP. GI & GII, SWL. GII)
(A) 4N (B) 5N (C) 7N (D) 8.7N

10. **Cos 60° = ______:** (SGD. GI)
(A) 0.5 (B) 1.732 (C) 0.866 (D) 0.577

11. **The direction of force F with x-axis is given by:** (SGD. GI & GII, BWP. GII, GRW. GI)
(A) $\theta = \text{Tan}^{-1}\frac{F_x}{F_y}$ (B) $\theta = \text{Tan}^{-1}\frac{F_y}{F_x}$ (C) $\theta = \text{Tan}\frac{F_x}{F_y}$ (D) $\theta = \text{Tan}\frac{F_y}{F_x}$

12. **In a right angle triangle length of base is 4 cm and perpendicular is 3cm, then its cos θ is equal to:** (DGK. GII)
(A) 0.8 (B) 0.75 (C) 1 (D) 0.6

13. **Sin 45° is equal to:** (BWP. GI, SGD. GI)
(A) 0 (B) 0.5 (C) 0.707 (D) 1

14. **In right angled triangle, base is 4cm and perpendicular is 3cm. Its tan θ is equal to:** (FBD. GI)
(A) 0.75 (B) 0.8 (C) 0.89 (D) 0.6

15. **In a right angled triangle length of bases is 4cm and perpendicular is 3cm, length of diagonal will be:** (MLN. GII)
(A) 2 cm (B) 5 cm (C) 4 cm (D) 6 cm

16. **Turning effect of a force is called:** (LHR. GI, SWL. GI, RWP. GI, BWP. GI)
(A) Torque (B) Moment (C) Couple (D) Torque and momentum

17. **SI unit of Torque is:** (MLN. GII)
(A) N.m (B) N s (C) Nm^{-1} (D) $N\ s^{-1}$

18. **The net torque acting on a rotating body with uniform speed is:** (LHR. GI)
(A) 1 (B) 2 (C) 5 (D) 0

19. **Torque depends on:** (FBD. GI)
(A) force and mass (B) mass and velocity
(C) force and moment arm (D) force and velocity

20. **Number of factors on which Torque depends:** (MLN. GI)
(A) 2 (B) 3 (C) 4 (D) 5

21. If force is 200 N and length of spanner is 0.15 m then torque will be: (MLN. GII)

(A) 30 Nm (B) 15 Nm (C) 20 Nm (D) 10 Nm

22. The formula of Torque is: (BWP. GI)

(A) L = F × E (B) E = F × T (C) τ = F × L (D) E = F × L

Answers

1. a couple	**2.** Like parallel forces	**3.** Net force	**4.** any number	
5. 5 N	**6.** tan θ	**7.** 1	**8.** 2	**9.** 8.7N
10. 0.5	**11.** $\theta = \tan^{-1}\frac{F_y}{F_x}$	**12.** 0.8	**13.** 0.707	**14.** 0.75
15. 5 cm	**16.** Torque	**17.** N.m	**18.** 0	**19.** force and moment arm
20. 2	**21.** 30 Nm	**22.** τ = F × L		

☆ Give short answer to the following questions.

1. What is difference between like and unlike parallel forces?
(LHR. GI, & GII, RWP. GI, SGD. GII, SWL. GI & GII, BWP. G I, GRW. G II, FBD. G II, MLN. G I, & G II)

Ans. Like Parallel Forces:

Weight of each apple

i. Like forces are also called like parallel force

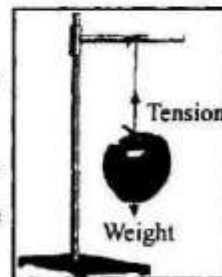
ii. Like force are the forces that have the same direction to each other.

iii. A bag has a large number of apples in it, the weight of all the apples is acted vertically downward so these all forces are in same direction, called like forces.

Unlike Parallel Forces:

i. Unlike forces are also called unlike parallel forces.

ii. Unlike forces are the forces that are in the opposite direction to each other.

iii. An apple is suspended by a string. The string is stretched by the weight of apple. Weight is acted downward but tension in the string is acted in upward direction. These are unlike forces.

2. How can we add the vectors by head to tail rule?
(FBD. GII, DGK. GI, GRW. GI, RWP. GI)

Ans. A graphical method is used to find the resultant of two or more forces or vectors, called the head to tail rule.

Head to tail rule method can be understood stepwise.

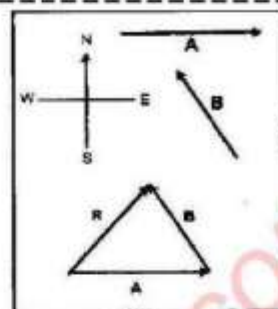
i. First select a suitable scale

ii. Draw the vectors of all the forces according to the scale; such as vectors **A** and **B**.

iii. Take any one of the vectors as first vector e.g., vector **A**.

iv. Draw next vector **B** such that its tail coincides with the head of the first vector **A**.

v. Draw the next vector for the third force (if any) with its tail coinciding with the head of the previous vector and so on.

vi. Draw a vector **R** as shown in the figure. The tail of vector **R** is at the tail of vector **A**, the first vector, while its head is at the head of vector **B**, the last vector.

Adding vectors by head to tail rule

3. What is resultant force? (DGK. GII, SWL. GI)

Ans. A resultant force is a single force that has the same effect as the combined effect of all the forces to be added.

4. How Head to Tail rule helps to find the Resultant of Forces? (BWP. GI, FBD. GI)

Ans. Head to tail rule is a graphical method of vector addition. In this method according to a selected scale we draw all the forces according to their magnitude. Take any force as a first vector and the second force starts from the head of first vector by starting it with a tail so that tail of second vector coincides with the head of first vector. Similarly, draw all the forces.

Such that head of previous vector coincides with the tail of next vector. By drawing all the vectors in this manner, draw a resultant force, which starts from the tail of first force and its head coincides with the head of last force.

5. Define perpendicular components. (LHR. GI, MLN. GII, DGK. GI, & GII, SGD. GII)

Ans. If a force is formed from two mutually perpendicular components then such components are called its perpendicular components.

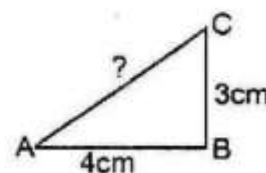
6. In a right angled triangle length of base is 4cm and its perpendicular is 3cm. Find its hypotenuse. (LHR. GI)

Sol. In ΔABC

By pythagora's theorem:

$$(Hyp.)^2 = (Base)^2 + (Perp.)^2$$
$$(AC)^2 = (AB)^2 + (BC)^2$$
$$(AC)^2 = 4^2 + 3^2$$
$$(AC)^2 = 16 + 9 = 25$$
$$(AC) = 5$$

Thus,

Length of hypotenuse is 5cm.

7. What do you meant by perpendicular components? Write down the formula to find their directions. (FBD. GII)

Ans. Perpendicular components: If a force is formed from two mutually perpendicular components then such components are called its perpendicular components.

Formula: To find their direction use the following formula:

$$\theta = \tan^{-1}\left(\frac{F_y}{F_x}\right)$$

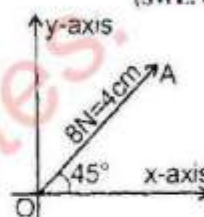
8. 8 Newton force makes an angle of 45° with x-axis. Represent it graphically. (SWL. GII)

Sol. Scale:

2N = 1cm

8N = 4cm

θ = 45°

with x-axis

9. What is difference between rigid body and axis of rotation? (LHR. GII)

Ans. Rigid Body:

A rigid body is the one that is not deformed by force or forces acting on it.

Axis of rotation:

Consider a rigid body. As it rotates, its particles move in fixed circles. A fixed line that passes through the centres of these circles is called axis of rotation of the body.

10. What will be the torque if a force of 150N is applied on a spanner of 10cm? (GRW. GI)

Sol. force = F = 150 N

Length of spanner = ℓ = 10 cm

torque = τ = ?

We know that

$$\tau = F \times \ell$$
$$\tau = 150 \times 0.1$$
$$\tau = 15 \text{ Nm}$$

11. What is meant by rigid body?

(GRW. GI & GII, RWP. GI, SWL. GI, BWP. GII, MLN. GI, SGD. GI, 2015)

Ans. Rigid Body: A rigid body is the one that is not deformed by force or forces acting on it.

12. Define torque and write its formula. (FBD. GI, SWL. GI, MLN. GII, DGK. GII, BWP. GI)

Ans. Torque: The turning effect of a force is called torque or moment of the force. It is

determined by the product of force F and its moment arm L. It is denoted as τ.

Formula: $\tau = L \times F$

13. Define axis of rotation. (SGD. GII, RWP. GI)

Ans. Consider a rigid body. As it rotates, its particles move in fixed circles. A fixed line that passes through the centres of these circles is called axis of rotation of the body.

14. Define moment arm. (RWP. GII, DGK. GI, & GII)

Ans. The perpendicular distance between the axis of rotation and the line of action of the force is called the moment arm of the force.

Moment arm is represented by distance (L)

15. A force of 100 N is applied perpendicularly on a spanner at a distance of 10 cm from a nut. Find the torque produced by the force. (DGK. GI)

Sol. Magnitude of Force = F = 100 N

Force applied perpendicular to the spanner

$= \theta = 90°$

Moment arm $= L = 10\text{cm} = 10 \times 10^{-2}\text{m}$

$= 0.1\ \text{m}$

Required: Find the torque produced by the force

$= \tau = ?$

Formula: By using the basic relation;

torque = Force×moment arm×sinθ

$\tau = F \times L \times \sin\theta$

Solution: By substituting the values in above equation;

$\tau = (100)\ (0.1)\ \sin 90°$

$\tau = (10)\ (1) \qquad \because \sin 90° = 1$

$\boxed{\tau = 10\text{Nm}}$

Ans: The torque produced by the force

$\tau = 10\ \text{Nm}$

16. Differentiate between Axis of Rotation and Moment Arm. (BWP. GII, LHR. GI)

Ans. Axis of rotation:

Consider a rigid body. As it rotates, its particles move in fixed circles. A fixed line that passes through the centres of these circles is called axis of rotation of the body.

Moment arm: The perpendicular distance between the axis of rotation and the line of action of the force is called the moment arm of the force.

17. **What is moment? Write its principle.** (GRW. GI & GII, FBD. GI)

Ans. Moment: The turning effect of a force is called torque or moment of the force.

Principle of moments: A body is balanced if the sum of clockwise moments acting on the body is equal to the sum of anticlockwise moments on it.

4.6+4.7	Centre of mass+Couple
4.8+4.9	Equilibrium+Stability and Position of centre of mass

☆ **Tick the correct answer.**

1. **Such a point where an applied force causes the system to move without rotation:** (FBD. GII)
   (A) Center of gravity (B) Center of mass
   (C) Center of weight (D) None of these
2. **The centre of gravity of an irregular shaped body can be found with the help of:** (SWL. GI, GRW. GI)
   (A) screw gauge (B) plumb line (C) metre rod (D) wedge
3. **The centre of gravity of a triangle is at:** (RWP. GI)
   (A) Centre (B) Point of intersection of medians
   (C) Centre of axis (D) Point of intersection of diagonals
4. **When centre of gravity is at the highest position, body will be in:** (SWL. GI)
   (A) neutral equilibrium (B) stable equilibrium
   (C) unstable equilibrium (D) none of these
5. **A couple is formed by:** (SGD. GII)
   (A) Two forces perpendicular to each other (B) Two like parallel forces
   (C) Two equal and opposite forces in the same line
   (D) Two equal and opposite forces not in the same line
6. **First condition of equilibrium is:** (LHR. GI & GII)
   (A) $\Sigma F = 0$ (B) $\Sigma \tau = 0$ (C) $\Sigma F = 0, \Sigma \tau = 0$ (D) All of these
7. **Racing cars are made stable by:**
   (GRW. GI & GII, BWP. GI, SWL. GI & GII, FBD. GI & GII, DGK. GI, MLN. GI, SGD. GI)
   (A) increasing their speed (B) decreasing their mass
   (C) decreasing their width (D) lowering their centre of gravity

8. **A body is in equilibrium when its:** (MLN. GII, LHR. GII)
   (A) Acceleration is uniform (B) Speed is uniform
   (C) Speed and acceleration are uniform (D) Acceleration is zero
9. **A body is in neutral equilibrium, when its centre of gravity is:** (RWP. GI)
   (A) at its highest position (B) at its lowest position
   (C) keep its height if displaced (D) situated at its bottom
10. **States of Equilibrium are:** (DGK. GII)
   (A) 4 (B) 3 (C) 2 (D) 1
11. **According to second condition of equilibrium must be zero:** (BWP. GII)
   (A) Angular Acceleration (B) Linear Acceleration
   (C) Rotational Force (D) Sum of Torque
12. **The Symbol of Sigma is:** (BWP. GII)
   (A) α (B) Σ (C) μ (D) $\cong$

Answers

1. Center of mass 2. plumb line 3. Point of intersection of medians
4. unstable equilibrium 5. Two equal and opposite forces not in the same line
6. $\Sigma F = 0$ 7. lowering their centre of gravity
8. Speed and acceleration are uniform 9. keep its height if displaced
10. 3 11. Sum of Torque 12. Σ

☆ **Give short answer to the following questions.**

1. **Define centre of mass.** (LHR. GII, DGK. GII, SGD. GII, FBD. GII, BWP. GII)

Ans. Centre of mass of a system is such a point where an applied force causes the system to move without rotation.

2. **Define centre of gravity.**
(LHR. GI, SGD. G II, SWL. GI & GII, DGK. G II, BWP. GII, MLN. GI, RWP. GII, FBD. GI, GRW. GI)

Ans. The centre of gravity of a body is defined as a point where the whole weight of the body appears to act vertically downward.

3. **What is difference between centre of mass and centre of gravity?**
(LHR. GII, DGK. GI)

Ans. **Centre of mass:** Centre of mass of a system is such a point where an applied force causes the system to move without rotation.

Centre of gravity: The centre of gravity of a body is defined as a point where the whole weight of the body appears to act vertically downward.

4. **Define neutral equilibrium.** (GRW. GI, MLN. GII, SGD. GII)

Ans. If a body remains in its new position when disturbed from its previous position, it is said to be in a state of neutral equilibrium.

5. Differentiate between torque and couple. (FBD. GII, SGD. GI, BWP. GII, SGD. GI)

Ans. Torque:

i. The turning effect of a force is called torque or moment of force

ii. To produce a torque we need only one force atleast.

iii. The torque is produced by a force F and the moment arm.

Couple:

i. A couple is formed by two unlike parallel forces of the same magnitude but not along the same line.

ii. To produce a couple we need two unlike parallel forces atleast.

iii. Torque of the couple = F×AB in this F represents force and AB represents the distance between two forces. The torque produced by a couple force F and F separated by the total distance (AB), that is the couple arm.

6. Explain couple with the help of an example. (SWL. GII, RWP. GII)

Ans. Couple:

A couple is formed by two unlike parallel forces of the same magnitude but not along the same line.

Example: When a driver turns a vehicle, he applies forces that produce a torque. This torque turns the steering wheel. These forces act on opposite sides of the steering wheel as shown in figure. These forces are equal in magnitude but opposite in direction. These two forces form a couple.

7. Differentiate between Stable and Neutral Equilibrium. (MLN. GI)

Ans. Stable equilibrium:

☆ A body is said to be in stable equilibrium if after a slight tilt it returns to its previous position.

☆ When a body is in stable equilibrium, its centre of gravity is at the lowest position. When it is tilted, its centre of gravity rises. It returns to its stable state by lowering its centre of gravity.

☆ A book placed on the table horizontally is an example of stable equilibrium.

Neutral equilibrium:

☆ If a body remains in its new position when disturbed from its previous, it is said to be in a state of neutral equilibrium.

☆ In neutral equilibrium, the centre of gravity of the body remains at the same height, irrespective to its new position.

☆ The rolling ball is an example of neutral equilibrium.

8. When a body is said to be in Equilibrium? **(MLN. GI, SGD. GI)**

Ans. A body is said to be in equilibrium if it follows both conditions of equilibrium.

A body is in equilibrium if net force acting on it is zero, and a body is said to be in equilibrium if the resultant torque acting on it is zero.

$\Sigma F = 0$, or $\Sigma F_y = 0$, $\Sigma F_x = 0$

$\Sigma \tau = 0$

9. Describe the first condition of Equilibrium. **(MLN. GI, FBD. GI, RWP. GII)**

Ans. The body is said to satisfy first condition for equilibrium if the resultant of all the forces acting on it is zero. Let 'n' number of forces $F_1, F_2, F_3, \ldots\ldots\ldots F_n$ are acting on a body such that

$$F_1 + F_2 + F_3 + \ldots\ldots\ldots + F_n = 0$$

or $\Sigma F_n = 0$

or $\Sigma F_x = 0$ and $\Sigma F_y = 0$

10. What is second condition of equilibrium? Write its mathematical form. **(SGD. GI, BWP. GI)**

Ans. According to the second condition for equilibrium, a body satisfies second condition for equilibrium when the resultant torque acting on it is zero. Mathematically;

$\Sigma \tau = 0$

11. Write down two conditions of equilibrium. **(RWP. GII, FBD. GII, LHR. GII, MLN. GII)**

Ans. First condition of equilibrium:

A body is said to satisfy first condition for equilibrium if the resultant of all the forces acting on it is zero.i.e. $\Sigma F = 0$

Second condition of equilibrium:

A body satisfies second condition of equilibrium when the resultant torque acting on it is zero. i.e. $\Sigma \tau = 0$

12. Why a body cannot be in equilibrium due to single force acting on it? **(BWP. GI, LHR. GI)**

Ans. For a body is said to be in equilibrium it is necessary that the net force acting on a body is zero and the sum of all the torques acting on a body is zero. These two conditions can not be satisfied if there is one force only. Because there is not any other force which nullify the effect of this force to keep the body in equilibrium and hence, this single force tends to move or rotate the body according to its point

of application. So, if a single force is applied on a body, it could not be in equilibrium i.e

$$\Sigma F \neq 0 \ , \ \Sigma \tau \neq 0$$

Moment arm is represented by distance (L)

13. Explain stable equilibrium by giving example. (GRW. GII)

Ans. A body is said to be in stable equilibrium if after a slight tilt it returns to its previous position. When a body is in stable equilibrium; its centre of gravity is at the lowest position. When it is tilted, its centre of gravity rises. Body returns to its stable state by lowering its centre of gravity.

14. Differentiate between Stable and Unstable Equilibrium. (MLN. GII, SWL. GI)

Ans. Stable Equilibrium:

☆ A body is said to be in stable equilibrium if after a slight tilt it returns to its previous position.

☆ In stable equilibrium, the centre of gravity is at the lowest position.

Unstable Equilibrium:

☆ If a body does not return to its previous position when sets free after a slightest tilt is said to be in unstable equilibrium.

☆ The centre of gravity of the body is at its highest position in the state of unstable equilibrium.

15. Why the height of vehicles is kept as low as possible? (FBD. GI, SGD. GI, SWL. GII)

Ans. Vehicles are made heavy at the bottom and their height is kept to be minimum. This lowers their centre of gravity and helps to increase their stability. Because to make them stable, their centre of mass must be kept as low as possible. Therefore, height of vehicles is kept as low as possible.

GRAVITATION

STUDENTS LEARNING OUTCOMES

After studying this unit, the students will be able to:

- state Newton's law of gravitation.
- explain that the gravitational forces are consistent with Newton's third law.
- explain gravitational field as an example of field of force.
- define weight (as the force on an object due to a gravitational field)
- calculate the mass of Earth by using law of gravitation.
- solve problems using Newton's law of gravitation.
- explain that value of 'g' decreases with altitude from the surface of Earth.
- discuss the importance of Newton's law of gravitation in understanding the motion of satellites.

Conceptual Linkage

This unit is built on
Gravitation –Science–V
Earth & Space –Science–VI
This unit leads to:
Gravitational Potential, Escape Velocity and Artificial Satellite – Physics–XI

SCIENCE, TECHNOLOGY AND SOCIETY CONNECTION:

- gather information to predict the value of the acceleration due to gravity 'g' at any planet or moon's surface using Newton's law of gravitation.
- Describe how artificial satellites keep on moving around the Earth due to gravitational force.

Major Concepts:

5.1 Law of Gravitation
5.2 Measurement of mass of earth
5.3 Variation of g with altitude
5.4 Motion of artifical satellites

Introduction: The first man who came up with the idea of gravity was Isaac Newton. It was an evening of 1665 when he was trying to solve the mystery why planets revolve around the Sun. Suddenly an apple fell from the tree under which he was sitting. The idea of gravity flashed in his mind. He discovered not only the cause of falling apple but also the cause that makes the planets to revolve around the Sun and the moon around the Earth. This unit deals with the concepts related to gravitation.

5.1 The Force of Gravitation

Q1. What is the force of gravitation? How it can be defined and proved?

Ans: Force of gravitation: The force due to which every body of the universe attracts every other body is called force of gravitation.

Examples:

⇒ According to the Newton the force which keeps the moon in its orbit is called force

of gravitation.

⇒ An apple falls on the Earth only due to force of gravitation.

Law of gravitation: According to Newton's law of universal gravitation.

Everybody in the universe attracts every other body with a force which is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centres.

Explanation:

Consider two bodies of masses m_1 and m_2.

The distance between the centres of masses is d as shown in the given figure.

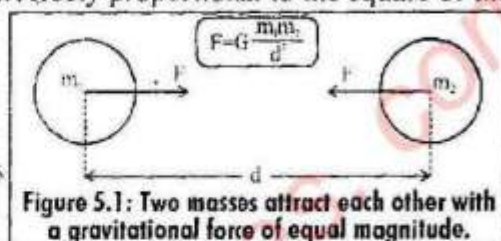



Figure 5.1: Two masses attract each other with a gravitational force of equal magnitude.

Value of force, according to the law of gravitation:

According to the law of gravitation, the gravitational force of attraction F with which two masses m_1 and m_2 separated by a distance d attract each other is given by.

$$F \propto m_1 m_2 \longrightarrow (1)$$

$$F \propto \frac{1}{d^2} \longrightarrow (2)$$

By combining eq (1) and (2):

$$F \propto \frac{m_1 m_2}{d^2}$$

For changing the sign of proportionality into equality, a constant is used.

$$F = G\frac{m_1 m_2}{d^2}$$

Here G is the proportionality constant.

Value of gravitational constant:

G is called the universal constant of gravitation. Its value is same everywhere. In SI units its value is 6.673×10^{-11} Nm^2 kg^{-2}.

Gravitational force of attraction between objects around us:

Due to small value of G, the gravitational force of attraction between objects around us is very small and we do not feel it.

Force with which Earth attracts to near by objects: The mass of the Earth is very large, it attracts nearby objects with a significant force.

Reason of weight of the object on Earth: The weight of an object on the Earth is the result of gravitational force of attraction between the Earth and the object.

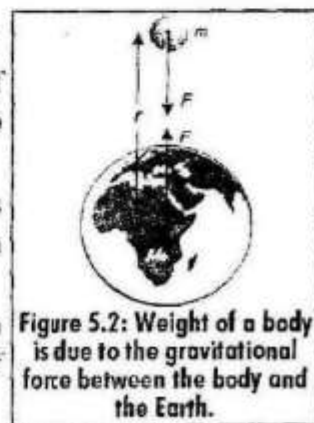



Figure 5.2: Weight of a body is due to the gravitational force between the body and the Earth.

Q2. What is the relation of law of gravitation and Newton's third law of motion.

Ans: Consider we have two objects of mass m_1 and m_2, which are present at distance (d) as shown in the given figure.

It is to be noted that mass m_1 attracts m_2 towards it with a force F, while mass m_2 attracts (m_1) towards it with a force of the same magnitude F but in opposite direction.

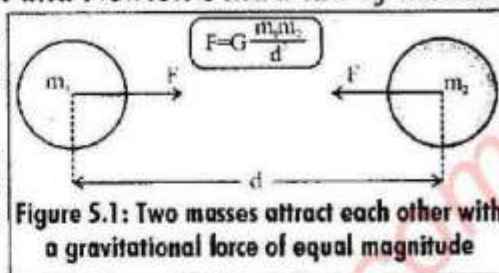



Figure 5.1: Two masses attract each other with a gravitational force of equal magnitude

Action and reactional force: If the force acting on m_1 is considered as action then the force acting on m_2 will be reaction.

Action and reaction due to force of gravitation are equal in magnitude but opposite in direction.

Newton's third law of motion: This is in consistence with Newton's third law of motion which states, to every action there is always an equal but opposite reaction.

Example 5.1

Two lead spheres each of mass 1000 kg are kept with their centres 1m apart. Find the gravitational force with which they attract each other.

Solution: Here $m_1 = 1000\ \text{kg}$

$m_2 = 1000\ \text{kg}$

$d = 1\text{m}$

Since $F = G\dfrac{m_1 m_2}{d^2}$

Putting the values, we get

$$F = 6.673 \times 10^{-11}\ \text{Nm}^2\ \text{kg}^{-2} \times \frac{1000\ \text{kg} \times 1000\ \text{kg}}{(1\text{m})^2}$$

$$F = 6.673 \times 10^{-5}\ \text{N}$$

Thus, gravitational force of attraction between the lead spheres is 6.673×10^{-5} N.

Q3. How will you define and explain the term gravitational field?

Ans: A gravitational field exists all around the Earth and this field is directed towards the centre of the Earth as shown by arrows in the given figure.

Figure 5.3: Gravitational field around the Earth is towards its centre.

Explanation:

Gravitational force: According to the Newton's law of gravitation, the gravitational force between a body of mass (m) and the Earth is given by:

$$F = G\frac{mMe}{r^2}$$

In this formula Me is the mass of the Earth and r is the distance of the body from the centre of the Earth.

Weight of the body: The gravitational force with which the Earth attracts a body, is called the weight of the body.

Field force: Gravitational force is a non-contact force.

For example, the velocity of a body, thrown up, goes on decreasing while on return its velocity goes on increasing.

This is due to the gravitational pull of the Earth acting on the body whether the body is in contact with the Earth or not. Such a force is called the field force.

Relation of gravitational field with distance:

In the gravitational field of the Earth, the gravitational field becomes weaker and weaker as we go farther and farther away from the Earth.

Mean gravitational field is inversely proportional to the distance.

Gravitational field strength of the Earth: In the gravitational field of the Earth the gravitational force per unit mass is called the gravitational field strength of the Earth.

Value of gravitational field strength:

At any place the value of gravitational field strength is equal to the value of g at that point. Near the surface of the Earth, the gravitational field strength is 10 Nkg^{-1}.

5.2 Mass of the Earth

Q4. How will you derive $Me = \frac{R^2 g}{G}$? Also find out the numerical value of the mass of the Earth. OR

How mass of Earth is determined? Find its value.

Ans: Consider a body of mass (m) on the surface of Earth as shown in given figure.

Figure 5.4: Weight of a body is equal to the gravitational force between the body and the Earth.

Suppose:

⇒ Mass of Earth is represented by Me.

⇒ Radius of Earth is represented by R.

⇒ The distance of the body from the centre of the Earth will also be equal to the radius R of the Earth.

Law of Gravitation: According to the law of Gravitation, the force with which Earth attracts a body is given by:

$$F = G\frac{mMe}{R^2} \longrightarrow (1)$$

But the force with which Earth attracts a body towards its centre is equal to its weight w.

Therefore:

$F = w = mg \longrightarrow (2)$

By comparing eq # (1) and (2)

$$mg = \frac{GmMe}{R^2}$$

$$g = \frac{GMe}{R^2}$$

$$\frac{R^2 g}{G} = Me$$

$$Me = \frac{gR^2}{G} \longrightarrow (3)$$

Numerical value of Mass of Earth Me:

As we know:

g = gravitational acceleration = $10ms^{-2}$

R = Radius of the Earth = 6.4×10^6m

G = Gravitational constant = $6.673\times10^{-11}\ Nm^2/kg^2$

By putting all the values in eq (3), the mass of Earth can be obtained.

$$Me = \frac{(10m/s^2)(6.4\times10^6m)^2}{6.673\times10^{-11}Nm^2/kg^2}$$

$$Me = \frac{(10)(6.4)\ (6.4)\times(10^{6\times2})}{6.673\times10^{-11}}$$

$$Me = \frac{409.6\times10^{12}}{6.673\times10^{-11}}$$

$Me = 61.38\times10^{12+11}$

$Me = 61.38\times10^{23}$

$Me = 6.0\times10\times10^{23}$

$Me = 6.0\times10^{24}$ kg.

So, Mass of the Earth is 6×10^{24} kg.

5.3 Variation of g with altitude

Q5. How value of g varies with altitude? Explain.

Ans: According to the relation $g = \frac{GM_e}{R^2}$, it can be clearly understood that value of acceleration due to gravity (g) depends on the radius of the Earth at its surface.

Relation of g with altitude: The value of acceleration due to gravity (g) is inversely proportional to the square of the radius of Earth.

$$g \propto \frac{1}{R^2}$$

It decreases with **altitude.**

Definition of altitude: Altitude is the height of an object or place above sea level.

The value of g is greater at sea level than at the hills.

Value of g at an altitude: Consider a body of mass (m) at an altitude (h) as shown in the given figure.

Figure 5.5: Weight of a body decreases as its height increases from the surface of the Earth

In this case, the distance of the body from the centre of Earth becomes R+h.

As we know:

$$g = \frac{GM_e}{R^2}$$

So by writing R + h instead of R in this case, we get

$$g_h = \frac{GM_e}{(R+h)^2}$$

By using above formula the value of g at an altitude can be easily found.

DO YOU KNOW?
Moon is nearly 3,80,000 km away from the Earth. It completes its one revolution around the Earth in 27.3 days.

⇒ According to the above equation, it is clear that at a height equal to one Earth radius above the surface of the Earth, g becomes one fourth of its value on the Earth.

⇒ According to the above equation it is also clear that at a distance of two Earths radius above the Earth's surface, the value of g becomes one ninth of its value on the surface of the Earth.

Example 5.2 ***Calculate the value of g, the acceleration due to gravity at an altitude 1000 km. The mass of the Earth is 6.0×10^{24} kg. The radius of the Earth is 6400 km.***

DO YOU KNOW?
Value of g on the surface of a celestial object depends on its mass and its radius. The value of g on some of the objects is given below:

Object	g (ms^{-2})
Sun	274.2
Mercury	3.7
Venus	8.87
Moon	1.62
Mars	3.73
Jupiter	25.94

Solution: Here

$R = 6400$ km

$h = 1000$ km

$M_e = 6.0 \times 10^{24}$ kg

$g_h = ?$

$R+h = 6400 \text{ km} + 1000 \text{ km} = 7400 \text{ km}$

$= 7.4 \times 10^6$ m

as $$g_h = G\frac{M_e}{(R+h)^2}$$

$$\therefore \quad g_h = \frac{6.673\times10^{-11}\,Nm^2kg^{-2}\times6.0\times10^{24}\,kg}{(7.4\times10^6\,m)^2}$$

$$g_h = 7.3\ N\,kg^{-1} = 7.3\ ms^{-2}$$

Thus the value of g, the acceleration due to gravity at an altitude of 1000 km will be $7.3\ ms^{-2}$.

MINIE EXERCISE

1. **Does an apple attract the Earth towards it?**

Ans: Yes, an apple attracts the Earth towards it but its attraction is very small and can not be felt.

2. **With what force an apple weighing 1N attracts the Earth?**

Ans: The force of attraction is equal to the weight of the object. So an apple weighing 1N attracts the Earth with one newton force.

3. **Does the weight of an apple increase, decrease or remain constant when taken to the top of a mountain?**

Ans: Weight of the apple, decrease when taken to the top of mountain due to less gravity of Earth.

5.4 Artificial Satellites

Q6. What are satellites? What are their types? How will you define and explain artificial satellites?

Ans: Satellites: An object that revolves around a planet is called a satellite.

DO YOU KNOW?

The height of a geostationary satellite is about 42,300 km from the surface of the Earth. Its velocity with respect to Earth is zero.

Types of satellites:

Basically satellites have two types.

(i) Natural satellites. (ii) Artificial satellites.

Natural satellite of the Earth:

The moon revolves around the Earth so moon is a natural satellite of the Earth.

DO YOU KNOW?

Global Positioning System (GPS) is a satellites navigation system. It helps us to find the exact position of an object anywhere on the land, on the sea or in the air. GPS consists of 24 Earth satellites. These satellites revolve around the Earth twice a day with a speed of 3.87 kms^{-1}.

Artificial satellites:

Scientists have sent many objects into space. Some of these objects revolve around the Earth. These are called artificial satellites.

Uses of artificial satellites:

Most of the artificial satellites, orbiting around the Earth are used for communication purposes.

Artificial satellites carry instruments or passengers to perform experiments in space.

Number of artificial satellites:

Large number of artificial satellites have been launched in different orbits around the Earth.

Figure 5.6: A satellite is orbiting around the Earth at a height *h* above the surface of the Earth.

Time taken by a satellite in one revolution:

Satellites take different time to complete their one revolution around the Earth depending upon their distance (h) from the Earth.

Example: **Time taken by communication satellites in one revolution:**

Communication satellites take 24 hours to complete their one revolution around the Earth. As Earth also completes its one rotation about its axis in 24 hours, hence these communication satellites appear to be stationary with respect to Earth.

Geostationary satellites: Geostationary satellites are those satellites whose velocity relative to Earth is zero. These satellites remain stationary with respect to the Earth at a height of about 42,300 km from the surface of the Earth.

Example: Communication satellites.

Function of geostationary orbit: Dish antennas sending and receiving the signals from geostationary orbit have fixed direction depending upon their location on the Earth.

Height of geostationary satellite: The height of a geostationary satellite is about 42, 300 km from the surface of the Earth. Its velocity with respect to Earth is zero.

Global Positioning System (GPS): Global Positioning System (GPS) is a satellites navigation system. It helps us to find the exact position of an object anywhere on the land, on the sea or in the air. GPS consists of 24 Earth satellites. These satellites revolve around the Earth twice a day with a speed of 3.87 kms^{-1}.

Q5. How motion of an artificial satellites can be found out? Prove its formula and write its value.

Ans: A satellite requires centripetal force that keeps it to move around the Earth. This necessary centripetal force is provided by the gravitational force of attraction between the satellite and the Earth.

Formula of motion of an artificial satellite:

Consider a satellite of mass (m) revolving round the Earth at an altitude (h) in an orbit of radius $r_o = (R + h)$ with orbital velocity v_o.

The centripetal force is given by equation.

$$F_c = \frac{mv_o^2}{r_o} \longrightarrow (1)$$

This centripetal force is provided by the gravitational force of attraction between the Earth and the satellite and is equal to the weight of the satellite w' (mg_h).

So, $F_c = w' = mg_h \longrightarrow (2)$

By comparing eq (1) and (2) we get,

$$mg_h = \frac{mv_o^2}{r_o}$$

$$g_h = \frac{v_o^2}{r_o}$$

$$r_o g_h = v_o^2$$

By taking underroot on both sides.

$$\sqrt{r_o g_h} = \sqrt{v_o^2}$$

$$v_o = \sqrt{r_o g_h}$$

So by putting the value of r_o, we get:

$$v_o = \sqrt{g_h (R + h)} \longrightarrow \quad (3)$$

Equation (3) gives the velocity, which a satellite must possess when launched in an orbit of radius $r_o = (R + h)$ around the Earth.

Suppose a satellite revolves close to the Earth:

Suppose a satellite is revolving close to the Earth, so its radius can be written as:

$$R >> h.$$

$$R + h \approx R$$

and $\quad g_h \approx g$

Now eq (3) becomes:

$$v_o = \sqrt{g\,R}$$

Value of speed of a satellite: A satellite revolving around very close to the Earth, has speed v_0 nearly 8 kms^{-1} or 29000 kmh^{-1}.

SUMMARY

- Newton's law of universal gravitation states that everybody in the universe attracts every other body with a force which is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centres.
- The Earth attracts a body with a force equal to its weight.
- It is assumed that a gravitational field exists all around the Earth due to the gravitational force of attraction of the Earth.
- In the gravitational field of the Earth, the gravitational force per unit mass is called the gravitational field strength of the Earth. It is 10 N kg^{-1} near the surface of the Earth.
- Acceleration $g = G\dfrac{M_e}{R^2}$

- Mass of Earth $M_e = \frac{R^2 g}{G}$
- g at an altitude h = $G\frac{M}{(R+h)^2}$
- An object that revolves around a planet is called a satellite.
- The moon revolves around the Earth so moon is a natural satellite of the Earth.
- Scientists, have sent many objects into space. Some of these objects revolve around the Earth. These are called artificial satellites.
- Orbital velocity v_o of a satellite is given as $v_o = \sqrt{g_h(R+h)}$

SOLVED QUESTIONS

5.1 Encircle the correct answer from the given choices:

(i) Earth's gravitational force of attraction vanishes at:

(a) 6400 km (b) infinity (c) 42300 km (d) 1000 km

(ii) Value of g increases with the:

(a) increase in mass of the body (b) increase in altitude
(c) decrease in altitude (d) none of the above

(iii) The value of g at a height one Earth's radius above the surface of the Earth is:

(a) 2 g (b) $\frac{1}{2}$ g (c) $\frac{1}{3}$ g (d) $\frac{1}{4}$ g

(iv) The value of g on moon's surface is 1.6 ms^{-2}. What will be the weight of a 100 kg body on the surface of the moon?

(a) 100 N (b) 160 N (c) 1000 N (d) 1600 N

(v) The altitude of geo-stationary orbits in which communication satellites are launched above the surface of the Earth is:

(a) 850 km (b) 1000 km (c) 6400 km (d) 42,300 km

(vi) The orbital speed of a low orbit satellite is:

(a) zero (b) 8 ms^{-1} (c) 800 ms^{-1} (d) 8000 ms^{-1}

Ans: **(i)** infinity **(ii)** decrease in altitude **(iii)** $\frac{1}{4}$g
(iv) 160 N **(v)** 42,300 km **(vi)** 8000 ms^{-1}

5.2 What is meant by the force of gravitation?

Ans: The force due to which every body of the universe attracts every other body is called force of gravitation.

5.3 Do you attract the Earth or the Earth attracts you? Which one is attracting with a larger force? You or the Earth.

Ans: Yes we attracts the Earth or Earth attracts us. Our body is very small, as compared to Earth so, we attract the Earth with a very small and insignificant force. Therefore

it is not felt by us.

Earth because of its larger mass attracts us with a larger and significant force.

5.4 What is a field force?

Ans: The weight of a body is due to the gravitational force with which the Earth attracts a body. Gravitational force is a non-contact force. For example, the velocity of a body, thrown up, goes on decreasing while on return its velocity goes on increasing. This is due to the gravitational pull of the Earth acting on the body whether the body is in contact with the Earth or not. Such a force is called the **field force**.

5.5 Why earlier scientists could not guess about the gravitational force?

Ans: The first man who came up with the idea of gravity was Isaac Newton. It was an evening of 1665, when he was trying to solve the mystery why planets revolve around the Sun. Before this, people were not familier even with the word gravity then how scientists could guess about the gravitational force.

5.6 How can you say that gravitational force is a field force?

Ans: Gravitational force is a non-contact force. For example, the velocity of a body, thrown up, goes on decreasing while on return its velocity goes on increasing. This is due to the gravitational pull of the Earth acting on the body whether the body is in contact with the Earth or not. Such a force is called the field force. It is assumed that a gravitational field exists all around the Earth and its direction is towards the centre of the Earth. The gravitational field becomes weaker and weaker as we go farther and farther away from the Earth.

5.7 Explain, what is meant by gravitational field strength?

Ans: The gravitational field becomes weaker and weaker as we go farther and farther away from the Earth. In the gravitational field of the Earth, the gravitational force per unit mass is called the gravitational field strength of the Earth. At any place its value is equal to the value of g at that point. Near the surface of the Earth, the gravitational field strength is 10Nkg^{-1}.

5.8 Why is law of gravitation important to us?

Ans: Newton's law of gravitation is very important to us. Because life can not imagine without this. This is the force of gravitation which is responsible for the survival of every object in the universe. We can determine the mass of Earth, density of Earth and orbital speed of satellite only because of this law. Artificial satellites are used for communication purposes, and carry instruments or passengers to perform experiments in space. These satellites require centripetal force that keeps them to move around the Earth. The gravitation force of attraction between the satellite and the Earth provides the necessary centripetal force.

5.9 Explain the law of gravitation.

Ans: According to Newton's law of universal gravitation, every body in the universe

attracts every other body with a force which is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centres.

$$F = \frac{G m_1 m_2}{d^2}$$

- By increasing the masses of objects, force of gravitation is also increased and by decreasing the masses of objects, force of gravitation is also decreased.
- By increasing the distance between objects force of gravitation decreased.

5.10 How can the mass of Earth be determined?

Ans: Consider a body of mass m on the surface of the Earth as shown in figure. Let the mass of the Earth be M_e and radius of the Earth be R. The distance of the body from the centre of the Earth will also be equal to the radius R of the Earth. According to the law of gravitation, the gravitational force F of the Earth acting on a body is given by:

Figure: Weight of a body is equal to the gravitational force between the body and the Earth.

$$F = G\frac{mM_e}{R^2} \quad \dots\dots\dots\dots (1)$$

But the force with which Earth attracts a body towards its centre is equal to its weight w. Therefore,

$$F = w = mg \quad \dots\dots\dots\dots (2)$$

$$\text{or} \quad mg = G\frac{mM_e}{R^2} \quad \dots\dots\dots\dots (3)$$

$$\therefore \quad g = G\frac{M_e}{R^2} \quad \dots\dots\dots\dots (4)$$

$$\text{and} \quad M_e = \frac{R^2 g}{G} \quad \dots\dots\dots\dots (5)$$

Mass Me of the Earth can be determined on putting the values in equation (5).

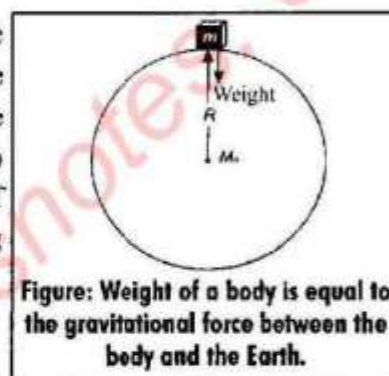
$$M_e = \frac{(6.4\times10^6\,m)^2\times10ms^{-2}}{6.673\times10^{-11}Nm^2kg^{-2}}$$

$$M_e = 6.0\times10^{24}\,kg$$

Thus, mass of the Earth is 6.0×10^{24} kg.

5.11 Can you determine the mass of our moon? If yes, then what you do need to know?

Ans: Yes, we can find out the mass of moon by using the law of gravitation.
As we know.

$$M = \frac{R^2 g}{G}$$

To find out the value of mass of moon, we need to know, following factors.

Radius of the moon (R)

Gravitational acceleration of the moon (g)

Gravitational constant (G).

5.12 Why does the value of g vary from place to place?

Ans: As we know that the value of gravitational acceleration depends on the radius of the Earth.

$$g = \frac{GM_e}{R^2}$$

Value of (g) is inversely proportional to the radius of Earth. This varies with height. By increasing height the value of g will decrease and by decreasing height the value of g will increase. This is the reason that the value of g is greater at sea level than at the hills.

5.13 Explain how the value of g varies with altitude.

Ans: As we know $g = \frac{GM_e}{R^2}$ This equation shows that the value of acceleration due to gravity g depends on the radius of the Earth at its surface. The value of g is inversely proportional to the square of the radius of the Earth. But it does not remain constant. It decreases with altitude. Altitude is the height of the body or place from the sea level. The value of g is greater at sea level than at the hills. Consider a body of mass (m) at an altitude (h). The distance of the body from the centre of the Earth becomes R+h.

$$g_h = G\frac{M_e}{(R+h)^2}$$

According to this equation, we come to know that at a height equal to one Earth radius above the surface of the Earth, g becomes one fourth of its value on the Earth. Similarly at a distance of two Earth's radius above the Earth's surface, the value of g becomes one ninth of its value on the Earth.

5.14 What are artificial satellites?

Ans: Scientists have sent many objects into space. Some of these objects revolve around the Earth. These are called artificial satellites.

5.15 How Newton's law of gravitation helps in understanding the motion of satellites?

Ans: A satellite requires centripetal force that keeps it to move around the Earth The gravitational force of attraction between the satellite and the Earth provides the necessary centripetal force. This centripetal force is introduced by the Newton. So in this way Newton's law of gravitation helps in understanding the motion of satellites.

5.16 On what factors the orbital speed of a satellite depends?

Ans: Orbital speed of the satellite depends only on gravitational acceleration of Earth and radius of the Earth. It is clear from the given formula. $v_o = \sqrt{gR}$

5.17 Why communication satellites are stationed at geostationary orbits?

Ans: Geostationary satellites take 24 hours to complete their one revolution around the Earth. As Earth also completes its one rotation about its axis in 24 hours, hence, these geostationary satellites appear to be stationary with respect to Earth.

SOLVED PROBLEMS

5.1 Find the gravitational force of attraction between two spheres each of mass 1000 kg. The distance between the centres of the spheres is 0.5 m.

Data: Mass of the first ball $= m_1 = 1000\text{kg}$

Mass of the second ball $= m_2 = 1000\text{kg}$

The distance between the centres of both spheres $= d = 0.5\text{m}$

$G = 6.673 \times 10^{-11}\ \text{Nm}^2\text{kg}^{-2}$

Required: Gravitational force between two spheres = F = ?

Solution: According to Newton's law of gravitation:

$$F = G\frac{m_1 m_2}{d^2}$$

By putting all the values in given formula, we get:

$$F = \frac{(6.673\times10^{-11})\times(1000)(1000)}{(0.5)^2}$$

$$F = \frac{6.673\times10^{6}\times10^{-11}}{0.25}$$

$$F = \frac{6.673\times10^{6-11}}{0.25}$$

$$F = \frac{6.673\times10^{-5}}{0.25}$$

$= 26.7 \times 10^{-5}$ N

$$\boxed{F = 2.67\times10^{-4}\text{N}}$$

Answer: The required force of attraction between two spheres is 2.67×10^{-4}N.

5.2 The gravitational force between two identical lead spheres kept at 1m apart is 0.006673 N. Find their masses.

Data: The distance between two spheres of lead $= d = 1\text{m}$.

Gravitational force between two spheres of lead $= F = 0.006673\text{N}$

Value of gravitational constant $= G = 6.673\times10^{-11}\text{Nm}^2\text{kg}^{-2}$.

Required: Masses of both spheres = ?

Mass of first sphere $= m_1 = ?$
Mass of second sphere $= m_2 = ?$

Formula: According to Newton's law of gravitation.

$$F = G\frac{m_1 m_2}{d^2}$$

Solution: $F = G\frac{m_1 m_2}{d^2}$

By rearranging the above equation.

$$\frac{Fd^2}{G} = m_1 m_2 \longrightarrow (1)$$

As we know the masses of both spheres are identical so, $m_1 = m_2 = m = ?$
By using equation # 1

$$\frac{Fd^2}{G} = m_1 m_2$$

$$\frac{Fd^2}{G} = m\,m$$

$$\frac{Fd^2}{G} = m^2$$

So,

$$m^2 = \frac{Fd^2}{G} \longrightarrow (2)$$

By putting the values in equation # 2, we get:

$$m^2 = \frac{(0.006673)(1)^2}{6.673\times10^{-11}}$$

$$m^2 = \frac{6.673\times10^{-3}\times1}{6.673\times10^{-11}}$$

$$m^2 = 1\times10^{-3}\times10^{+11}$$

$$m^2 = 1\times10^{8}$$

$$m^2 = 100000000$$

By taking underroot on both sides.

$$\sqrt{m^2} = \sqrt{100000000}$$

$$\boxed{m = 10{,}000\ kg}$$

Answer: The each sphere has mass 10,000kg.

5.3 Find the acceleration due to gravity on the surface of the Mars. The mass of Mars is 6.42×10^{23} kg and its radius is 3370 km.

Data: Mass of Mars $= M_m = 6.42\times10^{23}$ kg.

Radius of Mars $= R_m = 3370$ km $= 3370\times10^3$ m

$G = 6.67\times10^{-11}$ Nm^2 kg^{-2}

Required: The value of gravitational acceleration at the surface of Mars $= g_m = ?$

Solution: $g\dfrac{GM_m}{R_m^2}$

By putting values in this equation.

$$g_m = \frac{(6.673\times10^{-11})(6.42\times10^{23})}{(3370\times10^3)^2}$$

$$g_m = \frac{42.84\times10^{-11+23}}{11,356900\times10^6}$$

$$g_m = \frac{42.84\times10^{12}}{1.13569\times10^7\times10^6}$$

$$g_m = \frac{42.84\times10^{12}}{1.13569\times10^{13}}$$

$$g_m = 37.72\times10^{-1}$$

$$\boxed{g_m = 3.77 \text{ ms}^{-2}}$$

Answer: The acceleration due to gravity on the surface of the Mars is 3.77ms^{-2}.

5.4 The acceleration due to gravity on the surface of moon is 1.62 ms^{-2}. The radius of Moon is 1740 km. Find the mass of moon.

Data: The value of gravitational acceleration at the surface of moon $= g_m = 1.62$ms^{-2}.

Radius of moon $= R_m = 1740$km $= 1740\times10^3$m

Value of gravitational constant $= G = 6.673\times10^{-11}$ Nm^2 kg^{-2}.

Required: Mass of moon = m = ?

Formula: $g_m = \dfrac{GM_m}{R^2}$

Solution: $g_m = \dfrac{GM_m}{R_m^2}$ By putting the values in the given formula.

$$(1.62) = \frac{(6.67\times10^{-11})M_m}{(1740\times10^3)^2}$$

By rearranging the equation.

$$\frac{(1.62)(1740\times10^3)^2}{6.67\times10^{-11}} = M_m$$

$$\frac{(1.62)(3027600)\times10^6}{6.67\times10^{-11}} = M_m$$

$$M_m = \frac{4904712\times10^6}{6.67\times10^{-11}}$$

$M_m = 735339.1\times10^{6+11}$

$M_m = 735339.1\times10^{17}$

$M_m = 7.35\times10^5\times10^{17}$

$\boxed{M_m = 7.35\times10^{22}\text{ kg.}}$

Answer: The required mass of the moon is 7.35×10^{22} kg.

5.5 Calculate the value of g at a height of 3600 km above the surface of the Earth.

Data: Height from the surface of Earth = h = 3600km.

= h = 3600×10^3m

Value of gravitational constant = G = $6.67\times10^{-11}\text{Nm}^2\text{kg}^{-2}$.

Mass of Earth = M = 6.0×10^{24} kg.

Radius of Earth = R = 6400 km

Required: The value of g at the height of 3600km = ?

Formula: As we know:

$$g_h = \frac{GM_e}{(R+h)^2}$$

Solution: $g_h = \frac{GM_e}{(R+h)^2}$. By putting values, we get:

$$g_h = \frac{(6.673\times10^{-11})(6.0\times10^{24})}{(6400\times10^3+3600\times10^3)^2}$$

$$g_h = \frac{(6.673)(6.0)\times10^{-11}\times10^{24}}{(6400+3600)^2\times10^6}$$

$$g_h = \frac{40.038\times10^{-11}\times10^{24}\times10^{-6}}{(10,000)^2}$$

$$g_h = \frac{4.0038\times10^{+1}\times10^{-11}\times10^{24}\times10^{-6}}{10^{4\times2}}$$

$$g_h = 4.0038\times10^{+1}\times10^{-11}\times10^{24}\times10^{-6}\times10^{-8}$$

$$g_h = 4.00\times\cancel{10}^{25}\times\cancel{10}^{-25}$$

$$g_h = 4.00\times\text{m sec}^{-2}$$

$\boxed{g_h = 4\text{ msec}^{-2}}$

Answer: The required value of g at a height of 3600km above the surface of Earth is 4.0 $msec^{-2}$.

5.6 Find the value of g due to the Earth at geostationary satellite. The radius of the geostationary orbit is 48700 km.

Data: Radius of the geostationary orbit = 48700km

$= 48700 \times 100m$

$= 48700 \times 10^3 m$

Value of gravitational constant $= G = 6.673 \times 10^{-11} Nm^2kg^{-2}$

Mass of Earth $= M = 6.0 \times 10^{24}$ kg

Radius of Earth $= R = 6400$ km

$= 6400 \times 1000m$

$= 6400 \times 10^3 m$

Required: The value of g due to the Earth at geostationary satellite = ?

Formula: According to the Newton's law:

$$g = G\frac{M_e}{(R+h)^2}$$

Solution: By putting values in equation $g = G\frac{M_e}{(R+h)^2}$, we get.

$$g = \frac{(6.673\times10^{-11})(6.0\times10^{24})}{(6400+10^3+48700\times10^3)^2}$$

$$g = \frac{6.673\times6.0\times10^{-11}\times10^{24}}{(6400+48700)^2(10^3)^2}$$

$$g = \frac{40.038\times10^{13}}{(55100)^2\times10^6}$$

$$g = \frac{40.038\times10^{13-6}}{3036010000}$$

$$g = \frac{40.038\times10^7}{3.04\times10^9}$$

$$g = \frac{40.038\times10^{7-9}}{3.04}$$

$$g = 13.17\times10^{-2}$$

$$\boxed{g = 0.13 \text{ m sec}^{-2}}$$

Answer: The value of g due to the Earth at geostationary satellite = 0.13 ms^{-2}.

5.7 *The value of g is 4.0 ms^{-2} at a distance of 10000 km from the centre of the Earth. Find the mass of the Earth.*

Data: Distance from the centre of Earth = R+h = 10000km

R+h = 10000×10^3m

Value of g = 4.0 ms^{-2}

Value of gravitational constant = G = 6.673×10^{-11} Nm^{2}kg^{-2}

Value of the radius of the Earth = R = 6400km

R = 6400×10^3 m

Required: Mass of the Earth = M_e = ?

Formula: According to the Newton's law:

$$g_h = \frac{M_e \times G}{(R+h)^2}$$

Solution: Be rearranging the equation:

$$M_e = \frac{g\times(R+h)^2}{G}$$

By Putting the values we get.

$$M_e = \frac{4\times(10000\times10^3)^2}{6.673\times10^{-11}}$$

$$M_e = \frac{4\times(10000)^2\times(10^3)^2}{6.673\times10^{-11}}$$

$$M_e = \frac{4\times(10,000,000,0)\times10^6}{6.673\times10^{-11}}$$

$$M_e = \frac{4\times10^{14}}{6.673\times10^{-11}}$$

$M_e = 0.5994\times10^{14+11}$

$M_e = 0.5994\times10^{25}$

$M_e = 5.99\times10^{-1}\times10^{25}$

$\boxed{M_e = 5.99\times10^{+24}\ \text{kg}}$

Answer: The required value of mass of the Earth is 5.99×10^{24} kg.

5.8 *At what altitude the value of g would become one fourth than on the surface of the Earth.*

Data: Given value of gravitational acceleration = $\frac{g}{4} = \frac{10}{4} = 2.5$ m/sec^2

Mass of Earth = M_e = 6.0×10^{24} kg.

Radius of Earth = R = 6400 km = 6400×10^3m.

Value of gravitational constant = G = 6.673×10^{-11} Nm^{2}kg^{-2}

Required: Altitude at which the value of g would one fourth = ?

Formula: According to Newton's law of gravitation.

$$g_h = \frac{GM_e}{(R+h)^2}$$

Solution: As we know:

$$g_h = \frac{GM_e}{(R+h)^2}$$

Be rearranging the equation.

$$(R+h)^2 = \frac{GM_e}{g_h}$$

By taking square root on both side:

$$\sqrt{(R+h)^2} = \sqrt{\frac{GM_e}{g_h}}$$

$$(R+h) = \sqrt{\frac{GM_e}{g_h}}$$

$$h = \sqrt{\frac{GM_e}{g_h}} - R$$

By putting the values in this relation, we get.

$$h = \sqrt{\frac{(6.673\times10^{-11}\times6.0\times10^{24})}{2.5}} - 6400\times10^3$$

$$h = \sqrt{\frac{(6.673\times6)(10^{-11}\times10^{24})}{2.5}} - 6400\times10^3$$

$$h = \sqrt{\frac{40.038}{2.5}\times10^{-11+24}} - 6400\times10^3$$

$$h = \sqrt{16.0152\times10^{13}} - 6400\times10^3$$

$$h = 1.2,65512\times10^7 - 6400\times10^3$$

$$h = 12655.12\times10^3 - 6400\times10^3$$

$$h = (12655.12 - 6400)\times10^3$$

$$h = 6255.12\times10^3$$

$$\boxed{h = 6255.12 \text{ km}}$$

It is approximately equal to the radius of the Earth.

Answer: The required altitude at which the value of g would become one fourth is equal to one Earth's radius.

5.9 A polar satellite is launched at 850 km above Earth. Find its orbital speed.

Data: The height of polar satellite from the surface of Earth = h = 850 km

h = 850×1000m

h = 850×10^3m

Radius of the Earth = R = 6400km

Value of gravitational constant = G = $6.673\times10^{-11}\ Nm^2kg^{-2}$

Mass of the Earth = M_e = 6.0×10^{24} kg

Required: Orbital velocity of polar satellite = v_o = ?

Formula: As we know:

$$v_o = \sqrt{g_h(R+h)^2} \longrightarrow (1)$$

Solution: $v_o = \sqrt{g_h(R+h)^2}$

Firstly we have to find out the value of g_h.

For the value of g_h:

$$g_h = \frac{GM_e}{(R+h)^2}$$

By putting values, we get:

$$g_h = \frac{(6.673\times10^{-11})(6.0\times10^{24})}{[(6400+850)\times10^3]^2}$$

$$g_h = \frac{6.673\times6\times10^{-11}\times10^{24}}{(7250)^2\times10^6}$$

$$g_h = \frac{40.038\times10^{13}}{52562500\times10^6}$$

$$g_h = \frac{40.038\times10^{13}}{5.256\times10^7\times10^6}$$

$$g_h = \frac{40.038\times10^{13}}{5.256\times10^{13}}$$

$$\boxed{g_h = 7.62\ m\ sec^{-2}}$$

By putting the value of g_h in equation (1)

$$v_o = \sqrt{(7.62)(6400+850)\times10^3}$$

$$v_o = \sqrt{(7.62)(7250)\times10^3}$$

$$v_o = \sqrt{(7.62)(7250000)}$$

$$v_o = \sqrt{55,245,000}$$

$$\boxed{v_o = 7432.7\ m/sec}$$

Answer: The orbital velocity of polar satellites v = 7432.7 m/sec

5.10 A communication satellite is launched at 42000 km above Earth. Find its orbital speed.

Data: Height of the communication satellite = $h = 42000km$

$h = 42000 \times 1000m$

$h = 42000 \times 1000m$

Value of gravitational constant $= G = 6.67 \times 10^{-11}\ Nm^2\ kg^{-2}$.

Mass of Earth $= M_e = 6.0 \times 10^{24}$ kg

Radius of Earth $= R = 6400$ km $= 6400 \times 10^3$m

Required: Orbital velocity of communication satellite $= v_o = ?$

Formulas: As we know:

$$g_h = \frac{GM_e}{(R+h)^2}$$

$$v_o = \sqrt{g_h(R+h)} \longrightarrow (a)$$

Solution: As we know according to Newton's law of gravitation.

$$g_h = G\frac{M_e}{(R+h)^2}$$

By putting the values, we get:

$$g_h = \frac{(6.673\times10^{-11})(6.0\times10^{24})}{[(6400+42000)\times10^3]^2}$$

$$g_h = \frac{6.673\times6.0\times10^{-11}\times10^{24}}{(6400+42000)^2\times(10^3)^2}$$

$$g_h = \frac{40.038\times10^{13}}{(48400)^2\times10^6}$$

$$g_h = \frac{40.038\times10^{13-6}}{2,342,560,000}$$

$$g_h = \frac{40.038\times10^7}{2.342\times10^9}$$

$$g_h = 17.09\times10^{7-9}$$

$$g_h = 17.09\times10^{-2}$$

$$\boxed{g_h = 0.17m/sec^{-2}}$$

By putting the value of g_h in equation (a).

$$v_o = \sqrt{g_h(R+h)}$$

$$v_o = \sqrt{(0.17)(6400+42000)\times10^3}$$

$$v_o = \sqrt{(0.17)(48400)\times10^3}$$

$$v_o = \sqrt{8228\times10^3}$$

$$v_o = \sqrt{8.228\times10^3\times10^3}$$

$$v_o = \sqrt{8228\times10^3\times10^3}$$

$$v_o = \sqrt{2.876\times10^3 ms^{-1}}$$

$$\boxed{v_o = 2876\ ms^{-1}}$$

Answer: Orbital velocity of communication satellite = v_o = 2876 m/sec

OBJECTIVE TYPE QUESTIONS (MCQ'S+SHORT ANSWER) FROM PREVIOUS ANNUAL PAPERS OF ALL SECONDARY BOARDS
(LAHORE, GUJRANWALA, FAISALABAD, MULTAN, SAHIWAL, SARGODHA, RAWALPINDI, D.G. KHAN And BAHAWALPUR)

5.1 The Force of Gravitation
5.2 Mass of Earth

☆ **Tick the correct answer.**

1. **Earth's gravitational force vanishes at:** (LHR. GI, RWP. GII, SWL. GII)
   (A) 6400 km (B) Infinity (C) 42300 km (D) 1000 km
2. **The value of universal constant of gravitational (G) is:** (SWL. G)
   (A) $6.673\times10^{-11}Nmkg^{-2}$ (B) $6.673\times10^{-11}Nm^2kg^{-2}$
   (C) $6.673\times10^{-11}Nm^{-1}kg^2$ (D) $6.673\times10^{-11}Nm^{-2}kg^2$
3. **The idea of gravity was put up first by:** (RWP. GI)
   (A) Galileo (B) Newton (C) Hook (D) Einstein
4. **Near the surface of earth, the gravitational field strength is:** (DGK. GI & GII)
   (A) 5 N kg^{-1} (B) 9 Nkg^{-1} (C) 6 N kg^{-1} (D) 10 Nkg^{-1}
5. **The Mass of Earth is equal to:** (BWP. GI, MLN. GI, SGD. GI)
   (A) 6×10^4 kg (B) 6×10^{14} kg (C) 6×10^{24} N (D) 6×10^{24} kg

Answers

1. Infinity 2. $6.673\times10^{-11}Nm^2kg^{-2}$ 3. Galileo 4. 10 Nkg^{-1} 5. 6×10^{24} kg

☆ **Give short answer to the following questions.**

1. **Define law of gravitation.** (LHR. GI & GII, BWP. GI & GII, MLN. GII, GRW. GII)

Ans. Law of Gravitation: According to Newton's law of universal gravitation, every body in the universe attracts every other body with a force which is directly

proportional to the product of their masses and inversely proportional to the square of the distance between their centres.

$$F = \frac{Gm_1m_2}{d^2}$$

2. **What is the gravitational field strength near the surface of the earth?** (LHR. GI)

Ans. Near the surface of the Earth, the gravitational field strength is 10 Nkg^{-1}.

3. **Why can we not feel force of gravitation around us?** (GRW. GII)

Ans. Due to small value of G, the gravitational force of attraction between objects around us is very small and we do not feel it. Since the mass of Earth is very large, it attracts nearby objects with a significant force. The weight of an object on the Earth is the result of gravitational force of attraction between the Earth and the object.

4. **Why the law of gravitation is important for us?** (FBD. GI, MLN. GI)

Ans. Newton's law of gravitation is very important to us. Because life can not imagine without this. This is the force of gravitation which is responsible for the survival of every object in the universe. We can determine the mass of Earth, density of Earth and orbital speed of satellite only because of this law. Artificial satellites are used for communication purposes, and carry instruments or passengers to perform experiments in space.

5. **Give the value and unit of G in gravitational law.** (FBD. GII)

Ans. $G = 6.673 \times 10^{-11}\ Nm^2kg^{-2}$

6. **What is meant by Gravitational Field?** (MLN. GII, FBD. GI, DGK. GII)

Ans. The region around the Earth in which Earth attracts the other bodies is called gravitational field.

7. **What is meant by Gravitational force?** (SGD. GI, DGK.GII, LHR. GI, GRW. GI)

Ans. Gravitational force: The force due to which every body of the universe attracts every other body is called force of gravitation.

8. **What is field force?** (SGD. GII, MLN. GII, RWP. GI)

Ans. The weight of a body is due to the gravitational force with which the Earth attracts a body. Gravitational force is a non-contact force. For example, the velocity of a body, thrown up, goes on decreasing while on return its velocity goes on increasing. This is due to the gravitational pull of the Earth acting on the body whether the body is in contact with the Earth or not. Such a force is called the **field force.**

9. **Define gravitational field strength.** (SWL. GII, SGD. GI, RWP. GI & GII)

Ans. The gravitational field becomes weaker and weaker as we go farther and farther away from the Earth. In the gravitational field of the Earth, the gravitational force per unit mass is called the gravitational field strength of the Earth. At any place its value is equal to the value of g at that point. Near the surface of the Earth, the gravitational field strength is $10Nkg^{-1}$.

10. What is the direction of gravitational field? (DGK. GII)

Ans. The direction of gravitational field is toward the centre of the earth.

11. Write the value of Mass of Earth with Unit. (MLN. GI)

Ans. Mass of Earth $= 6.0 \times 10^{24}$ Kg

12. If $R=6.4\times10^6$m, $G=6.673\times10^{-11}$ Nm^2kg^{-2} and $g=10ms^{-2}$, then find Mass of earth?

Sol. We know that (RWP. GII)

$$M_e = \frac{R^2g}{G}$$

$G = 6.673 \times 10^{-11}$ Nm^2Kg^{-2}, $g = 10ms^{-2}$,
$R = 6.4 \times 10^6m$

Put the above values

$$M_e = \frac{(6.4\times10^6)^2\times(10^1)}{6.673\times10^{-11}}$$

$$M_e = \frac{6.4\times6.4\times10^{12}\times10^1}{6.673\times10^{-11}}$$

$$M_e = 6\times10^{13+11}$$

$$M_e = 6\times10^{24}kg$$

5.3 Variation of g with altitude

5.4 Artificial Satellites

☆ Tick the correct answer.

1. The value of 'g' at the surface of moon is: (GRW. GI, MLN. GI, LHR. GII)

(A) $1.06ms^{-2}$ (B) $1.6ms^{-2}$ (C) 1.6ms (D) $0.16ms^{-2}$

2. The value of g at a height of one earth's radius above the surface of the earth is: (SWL. GI, SGD. GII, BWP. GII, RWP. GI)

(A) 2g (B) $\frac{1}{2}g$ (C) $\frac{1}{3}g$ (D) $\frac{1}{4}g$

3. The value of 'g' on Mars is: (SGD. GI)

(A) $3.73ms^{-2}$ (B) $1.62ms^{-2}$ (C) $8.87ms^{-2}$ (D) $10\ ms^{-2}$

4. Moon completes its one revolution around the earth in: (LHR. GII, BWP. GII)

(A) One day (B) 17.3 days (C) 22.3 days (D) 27.3 days

5. The orbital speed of a low orbit satellite is: (FBD. GI & GII, LHR. GI, MLN. GII)

(A) 0 (B) $8ms^{-1}$ (C) $800ms^{-1}$ (D) $8000ms^{-1}$

6. The velocity of Geostationary satellite with respect to earth is: (RWP. GI)

(A) zero (B) $5kmh^{-1}$ (C) $10kmh^{-1}$ (D) $15kmh^{-1}$

Answers

1.	$1.6ms^{-2}$	2.	$\frac{1}{4}g$	3.	$3.73ms^{-2}$
4.	27.3 days	5.	$8000ms^{-1}$	6.	zero

☆ **Give short answer to the following questions.**

1. **Write equation of gravitational acceleration at height h from the surface of earth according to Newton's law of gravitation.** (GRW. GI)

Ans. The equation of gravitational acceleration at heigh h is

$$g_h = G\frac{M_e}{(R+h)^2}$$

2. **Value of 'g' decreases with height. Give its reason.** (SWL. GII)

Ans. The value of "g" decreases with altitude. Altitude is the height of an object or place above sea level. The value of g is greater at sea level than at the hills.

3. **If R is doubled then what will be change in $g = \frac{GM_e}{R^2}$ equation?** (SWL. GII, LHR. GI)

Sol. $g = \frac{GM_e}{R^2}$

Put $R = 2R$

$$g = \frac{GM_e}{(2R)^2} = \frac{GM_e}{4R^2}$$

$$g = \frac{1}{4}\left(\frac{GM_e}{R^2}\right)$$

If we put R = 2R in equantion $g = \frac{GM_e}{R^2}$, then the value of "g" becomes one-fourth.

4. **Why is the value of 'g' is different at different places?** (SGD. GI)

Ans. As we know that the value of gravitational acceleration depends on the radius of the Earth.

$$g = \frac{GM_e}{R^2}$$

Value of (g) is inversely proportional to the radius of Earth. This varies with height. By increasing height the value of g will decrease and by decreasing height the value of g will increase. This is the reason that the value of g is greater at sea level than at the hills.

5. **On which factor Gravitational Acceleration depends? Describe its change with respect to height.** (MLN. GI)

Ans. The value of gravitational acceleration "g" depends upon the radius of the Earth at its surface. The value of g is inversely proportional to the square of the radius of the Earth. But it does not remain constant. It decreases with altitude.

$$g = G\frac{M_e}{R^2}$$

6. **Why does the value of "g" vary from place to place?** (SWL. GI, BWP. GII)

Ans. As we know that the value of gravitational acceleration depends on the radius of the

Earth.

$$g = \frac{GM_e}{R^2}$$

Value of (g) is inversely proportional to the radius of Earth. This varies with height. By increasing height the value of g will decrease and by decreasing height the value of g will increase. This is the reason that the value of g is greater at sea level than at the hills.

7. Describe the change in "g" gravitational acceleration with height. **(DGK. GII)**

Ans. As we know $g = \frac{GM_e}{R^2}$ This equation shows that the value of acceleration due to gravity g depends on the radius of the Earth at its surface. The value of g is inversely proportional to the square of the radius of the Earth. But it does not remain constant. It decreases with altitude. Altitude is the height of the body or place from the sea level. The value of g is greater at sea level than at the hills. Consider a body of mass (m) at an altitude (h). The distance of the body from the centre of the Earth becomes R+h.

$$g_h = G\frac{M_e}{(R+h)^2}$$

According to this equation, we come to know that at a height equal to one Earth radius above the surface of the Earth, g becomes one fourth of its value on the Earth. Similarly at a distance of two Earths radius above the Earth's surface, the value of g becomes one ninth of its value on the Earth.

8. Describe the navigation system. **(LHR. GII)**

Ans. Global positioning system (GPS) is a satellites navigation system. It helps us to find the exact position of an object anywhere on the land, on the sea or in the air GPS consists of 24 Earth satellites. These satellites revolve around the Earth twice a day with a speed of 3.87 kms^{-1}.

9. What is height and speed of Geo Stationary Satellite from the surface of the earth? **(LHR. GII, FBD. GII, MLN. GI)**

Ans. The height of a geostationary satellite is about 42300 km from the surface of the Earth. Its speed with respect to Earth is zero.

10. Why communication satellites are stationed at geostationary orbits? **(GRW. GI, SWL. GII, DGK. GI)**

Ans. Geostationary satellites take 24 hours to complete their one revolution around the Earth. As Earth also completes its one rotation about its axis in 24 hours, hence, these geostationary satellites appear to be stationary with respect to Earth.

11. What is meant by global positioning system? **(GRW. GII, RWP. GI, BWP. GI)**

Ans. Global Positioning System (GPS) is a satellites navigation system. It helps us to find the exact position of an object anywhere on the land, on the sea or in the air.

GPS consists of 24 Earth satellites. These satellites revolve around the Earth twice a day with a speed of 3.87 kms^{-1}.

12. What are the artificial satellites? (FBD. GI, SWL. GI, DGK. GI)

Ans. Scientists have sent many objects into space. Some of these objects revolve around the Earth. These are called artificial satellites.

13. Define geostationary orbit. (SWL. GI, GRW. GII)

Ans. Communication satellites take 24 hours to complete their one revolution around the Earth. As Earth also completes its one rotation about its axis in 24 hours, hence these communication satellites appear to be stationary with respect to Earth. It is due to this reason that the orbit of such a satellite is called geostationary orbit.

14. What is communication satellite? Write down its height from surface of earth. (RWP. GI)

Ans. Scientists have sent many objects into space. Some of these objects revolve around the Earth. Some of these are used for communication purposes. These satellites are at a height of about 42, 300 km from the surface of Earth.

15. On what factors, the orbital speed of Satellite depends? (BWP. GI, SGD. GI)

Ans. Orbital speed of the satellite depends only on gravitational acceleration of Earth and radius of the Earth. It is clear from the given formula. $v_o = \sqrt{gR}$

16. Write the formula of artificial satellite's orbital speed. (GRW. GI)

Ans. The speed of artificial satellite is find out by the formula:

$$V_o = \sqrt{g_h(R+h)}$$

17. What is a satellite and Geostationary satellite? (SGD. GII)

Ans. Satellites: An object that revolves around a planet is called a satellite.

Geostationary satellites: Geostationary satellites are those satellites whose velocity relative to Earth is zero. These satellites remain stationary with respect to the Earth at a height of about 42,300 km from the surface of the Earth.

Example: Communication satellites.

18. Write two uses of Artificial Satellite. (BWP. GII)

Ans. 1. Most of the artificial satellites, orbiting around the Earth are used for communication purposes.

2. Artificial satellites carry instruments or passengers to perform experiments in space.

WORK AND ENERGY

STUDENTS LEARNING OUTCOMES

After studying this unit, the students will be able to:

- define work and its SI unit.
- calculate work done using equation
  - Work=force×distance moved in the direction of force
- define energy, kinetic energy and potential energy. State unit of energy.
- prove that kinetic energy $E_K = \frac{1}{2}mv^2$ and potential energy $E_P = mgh$. Solve problems using these equations.
- list the different forms of energy with examples.
- describe the processes by which energy is converted from one form to another with reference to
  - fossil fuel energy
  - hydroelectric generation
  - solar energy
  - nuclear energy
  - geothermal energy
  - wind energy
  - biomass energy

Potential energy
Energy in
Energy out
Kinetic energy
Kinetic energy

Conceptual Linkage

This unit is built on:
Energy —Science-V
Input, output & efficiency —Science-VII

This unit leads to:
Energy & Work -Physics-XI

- state mass energy equation $E=mc^2$ and solve problems using it.
- describe the process of electricity generation by drawing a block diagram of the process from fossil fuel input to electricity output.
- list the environmental issues associated with power generation.

- differentiate energy sources as non renewable and renewable energy sources with examples of each.
- explain by drawing energy flow diagrams through steady state systems such as filament lamp, a power station, a vehicle travelling at a constant speed on a level road.
- define efficiency of a working system and calculate the efficiency of an energy conversion using the formula.
- Efficiency = energy output converted into the required form / total energy input.
- explain why a system cannot have an efficiency of 100%.
- define power and calculate power from the formula:
- Power = work done / time taken

Major Concepts:
6.1 Work
6.2 Energy
6.3 Kinetic energy
6.4 Potential energy
6.5 Forms of energy
6.6 Interconversion of energy
6.7 Major sources of energy
6.8 Efficiency
6.9 Power

- define the unit of power "watt" in SI and its conversion with horse power.
- solve problems using mathematical relations learnt in this unit.

INVESTIGATION SKILLS:

- investigate conservation of energy of a ball rolling down an inclined plane using double inclined plane and construct a hypothesis to explain the observation.
- compare personal power developed for running upstairs versus walking upstairs using a stopwatch.

SCIENCE, TECHNOLOGY AND SOCIETY CONNECTION:

- analyse using their or given criteria, the economic, social and environmental impact of various energy sources. [e.g. (fossil fuel, wind, falling water, solar, biomass, nuclear, thermal energy and its transfer (heat)}
- analyse and explain improvements in sports performance using principles and concepts related to work, kinetic and potential energy and law of conservation of energy (e.g. explain the importance of the initial kinetic energy of a pole vaulter or high jumper).
- search library or internet and compare the efficiencies of energy conversion devices by comparing of energy input and useful energy output.
- explain principle of conservation of energy and apply this principle to explain the conversion of energy from one form to another such as a motor, a dynamo, a photo cell and a battery, a freely falling body.
- list the efficient use of energy in the context of the home, heating and cooling of buildings and transportation.

Introduction: Generally, work refers to perform some task or job. In science, work has precise meaning. For example, a man carrying a load on his head is not doing any work. Scientifically, work is done only when an effort or force moves an object. When work is done, energy is used. Thus, work and energy are related to each other. The concept of energy is an important concept in Physics. It helps us to identify all the possible changes that occur when work is done. This unit deals with the concepts of work, power and energy.

6.1 Work

Q1. What is work? Write a detail note on work.

Ans: WORK:

Work is said to be done when a force acting on a body displaces it in the direction of the force.

Explanation:

Suppose a Force (F) acting on a body displaces it through some distance (S) in the direction of force as shown in given figure.

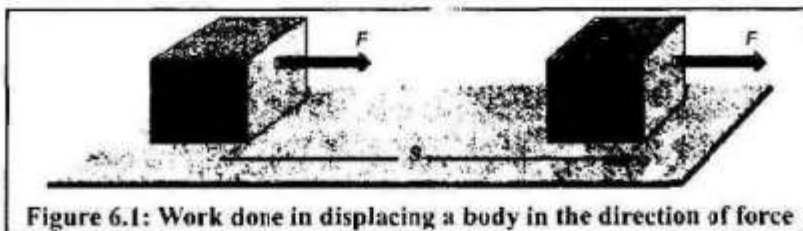



Figure 6.1: Work done in displacing a body in the direction of force

So work done can be found out by the following relation;

Work done = Force × displacement

Greater is the force acting on a body and longer is the distance moved by it, larger would be the work done.

Formula: Mathematically, work is a product of force (F) and displacement (S) in the direction of force.

$$W = F \times S$$

Thus no work will be done if either F or S is zero.

If force and displacement do not have same direction:

Sometimes the force and displacement do not have the same direction such as shown in given figure.

Figure 6.2: Work done by a force inclined with the displacement

In this case, force **F** is making an angle θ with the surface on which body is moved.

Rectangular components of vector F:

Vector F can be resolved into its rectangular components Fx and Fy.;

Horizontal component of vector F: Horizontal component of vector F can be represented by Fx. It can be found by following formula.

$$F_x = F\cos\theta$$

Vertical component of vector F: Vertical component of vector F can be represented by Fy, it can be found by following formula.

$$F_y = F\sin\theta$$

In case when force and displacement are not parallel then only the x-component F_x parallel to the surface and not the y-component F_y.

$$\begin{aligned} \text{Hence} \quad W &= F \times S \\ &= (F\cos\theta)S \\ W &= FS\cos\theta \end{aligned}$$

Work is done when force acting on a body displaces it, in the direction of force:

Scalar quantity: Work is a scalar quantity, because it needs only magnitude to describe it completely.

Factors on which work depends: Work depends on the force acting on a body, displacement of the body and the angle between them.

Unit of Work: SI unit of work is joule (J).

Definition of joule: The amount of work is one joule when a force of one newton displaces a body through one metre in the direction of force.

Thus $1J = 1N \times 1m$

Bigger units of work:

Bigger units of work are given as.

1 kilo joule (kJ) = 1000 J = 10^3 J

1 mega joule (MJ) = 1000,000 J = 10^6 J

MINI EXERCISE

A crate is moved by pulling the rope attached to it. It moves 10 m on a straight horizontal road by a force of 100 N. How much work will be done if.

1. **The rope is parallel to the road.**
2. **The rope is making an angle of 30° with the road.**

1. Data:

Force = F = 100N

Distance = S = 10m

Required: Work = W = ?

Formula: $W = F \times S$

Solution: By putting values in the given formula, we get.

$W = F \times S$

$W = 100 \times 10$

$\boxed{W = 1000J}$

2. Data:

Force = F = 100N

Distance = S = 10m

Angle which rope is making with the road = 30°

Required: Work done = W = ?

Formula: $W = FS\cos\theta$.

Solution: By putting values, we get.

$W = FS\cos\theta$

$W = 100 \times 10 \cos(30^\circ)$

$W = 1000\ (0.866)$

$\boxed{W = 866.0J}$

Example 6.1 ***A girl carries a 10 kg bag upstairs to a height of 18 steps, each 20 cm high. Calculate the amount of work she has done to carry the bag. (Take g = 10 ms^{-2}).***

Solution: Mass of the bag $m = 10$ kg

Weight of the bag $w = mg$

$= 10\ kg \times 10\ ms^{-2}$

$= 100\ N$

To carry the bag upstairs, the girl exerts an upward force F equal to w, the weight of the bag. Thus

$F = 100N$

Height $h = 18 \times 0.2m = 3.6\ m$

$W = F\ h$

$= 100 \times 3.6 = 360\ J$

The girl has done 360 J of work

6.2 Energy

Q2. What is energy? Explain with examples. What are types of energy?

Ans: Energy: A body possesses energy if it is capable to do work.

The energy is an important and fundamental concept is science. It links almost all the natural phenomena. When it is said that a body had energy, it means, that it has the ability to do work.

Example: Water running down the stream has the ability to do work, so it possesses energy. The energy of running water can be used to run water mills or water turbines.

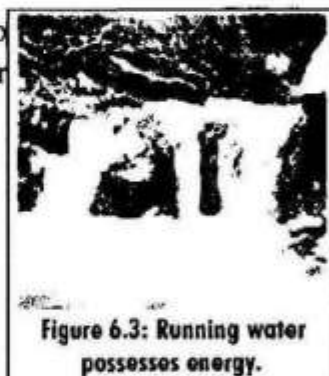



Figure 6.3: Running water possesses energy.

Types of energy:

Energy exists in various types which are given below.

1. Mechanical energy
2. Heat energy
3. Light energy
4. Sound energy
5. Electrical energy
6. Chemical energy
7. Nuclear energy

Types of mechanical energy: Mechanical energy possessed by a body is of two types.

1. Kinetic energy
2. Potential energy

Energy can be transformed from one form into another.

6.3 Kinetic energy

Q3. What is kinetic energy? Give examples. How formula of kinetic energy can be proved?

Ans: Kinetic energy:

The energy possessed by a body due to its motion is called its kinetic energy.

Example # 1:

Wind is air in motion, wind energy can be used for doing various things.

It drives windmills and pushes sailing boats.

Figure 6.4: Energy of the wind moves the sailing boats.

Example # 2: Fast moving water in a river can carry wooden logs through large distances and can also be used to drive turbines for generating electricity.

Example # 3: A moving body has kinetic energy, because it can do work due to its motion. As soon as, body stops moving, it looses all of its kinetic energy.

Formula of K.E can be proved as: Consider a body of mass (m) moving with velocity (v.) The body stops after covering some distance (S) due to some opposing force such as force of friction acting on it.

The body possesses kinetic energy and is capable to do work against opposing force F until all of its kinetic energy is used up.

As we know,

Kinetic energy of the body = Work done by it due to motion

$$K.E = \text{Force} \times \text{displacement}$$

$$K.E = F \times S. \longrightarrow (1)$$

In this case

$$v_i = v$$

$$v_f = 0$$

According to Newton's second law of motion:

$$F = ma$$

$$a = -\frac{F}{m}$$

In the given case, the motion is opposed, hence (a) is negative.

According to 3rd equation of motion:

$$2aS = v_f^2 - v_i^2$$

By putting the all values in this equation

$$2\left(\frac{-F}{m}\right)S = (o)^2 - (v)^2$$

$$2\left(\frac{-FS}{m}\right) = -v^2$$

$$2\left(\frac{-FS}{m}\right) = -v^2$$

Both sides of equation have minus sign, so these signs are cancelled out. So,

$$2\frac{FS}{m} = v^2$$

$$FS = \frac{1}{2} mv^2 \longrightarrow (2)$$

From eq (1) and (2) following relation can be obtained.

$$K.E = \frac{1}{2} mv^2 \longrightarrow (3)$$

Equation (3) gives the kinetic energy possessed by a body of mass (m) moving with velocity (v).

Example 6.2 ***A stone of mass 500g strikes the ground with a velocity of 20ms⁻¹. How much is the kinetic energy of the stone at the time it strikes the ground?***

Solution: $m = 500\text{ g} = 0.5\text{ kg}$

$v = 20\text{ ms}^{-1}$

Since $K.E = \frac{1}{2}mv^2$

$$K.E = \frac{1}{2} 0.5\text{kg} \times (20\text{ms}^{-1})^2$$

$$K.E. = \frac{1}{2} 0.5\text{kg} \times 400\text{m}^2\text{s}^{-2}$$

$$K.E. = 100\text{ J}$$

Thus, the kinetic energy of the stone is 100J as it strikes the ground.

6.4 Potential energy

Q4. What is potential energy? Give examples to explain. Prove the relation P.E=mgh:

Ans: Potential energy:

The ability of a body to do work due to its position is known as its potential energy.

OR

The kind of energy which a body possesses due to its position is called its potential energy.

Example # 1: Stored water before it runs down possesses potential energy, due to its height.

Example # 2: A hammer raised to some height has the ability to do work because it possesses potential energy.

Hammer raised up

Example # 3 (Elastic potential energy):

A stretched bow has potential energy due to its stretched position. When released, the stored energy of the bow pushes the arrow out of it.

The energy present in the stretched bow is called elastic potential energy.

Example # 4. **Gravitational potential energy**: The energy present in a body due to its

height is called gravitational potential energy.

The potential energy possessed by a hammer is due to its height.

P.E = mgh, this relation can be proved as:

Consider a body of mass (m). Let it be raised through height (h) from the ground. The body will acquire potential energy equal to the work done in lifting it to height h.

mass of the body = m

Force lifting the body = F = w = mg

height attained = S = h

Work done on the body = W = FS

As we know,

Fore = Weight , Distance = height

So $F = w$, $S = h$

Work done on the body = $W = w \times h \longrightarrow (1)$

According to the formula of weight

Weight = mass × gravitational acceleration

$w = mg$

By putting the value of weight in eq (1)

Work done on the body = W = mgh

The work done W in raising the body to height h appears as its potential energy.

Potential energy of the body = mgh

P.E = mgh.

Thus, the potential energy possessed by the body with respect to the ground is mgh and is equal to the work done in lifting it through height h.

Example 6.3 ***A body of mass 50 kg is raised to a height of 3 m. What is its potential energy? (g = 10 ms^{-2})***

Solution: mass m = 50 kg

height h = 3m

g = $10 ms^{-2}$

as P.E = m g h

∴ P.E = $50 kg \times 10 ms^{-2} \times 3 m$

P.E = 50 × 10 × 3 J = 1500 J

The potential energy of the body is 1500 J.

Example 6.4 ***A force of 200 N acts on a body of mass 20 kg. The force accelerates the body from rest until it attains a velocity of 50 ms^{-1}. Through what distance the force acts?***

Solution: Force F = 200 N

Mass m = 20 kg

Velocity $v = 50\ ms^{-1}$

Distance $S = ?$

Since Work done on the body = K.E. gained by it.

$$\therefore \quad FS = \frac{1}{2}mv^2$$

$$S = \frac{(20\,kg)\times(50\,ms^{-1})^2}{2\times 200N} = 125m$$

Thus, the distance moved by the body is 125 m.

6.5 Forms of energy

Q5. What are the main forms of energy? Discuss them briefly.

Ans: Energy exists in various forms. Some of the main forms of energy are given in the following figure.

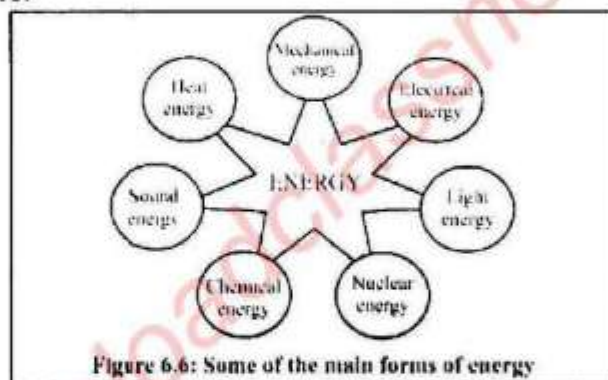



Figure 6.6: Some of the main forms of energy

1. Mechanical energy: The energy possessed by a body both due to its motion or position is called mechanical energy.

Examples: Water running down a stream, wind, a moving car, a lifted hammer, a stretched bow, a catapult or a compressed spring etc. possess mechanical energy.

Figure 6.7: A water mill

2. Heat energy: Heat is a form of energy given out by hot bodies.

Sources of heat energy:

⇒ Large amount of heat is obtained by burning fuel.

⇒ Heat is produced when motion is opposed by frictional forces.

⇒ The Sun is the main source of heat energy.

Example: The foods which are eaten by humans provide heat energy to them.

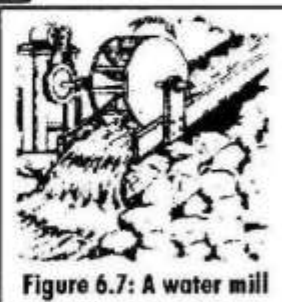
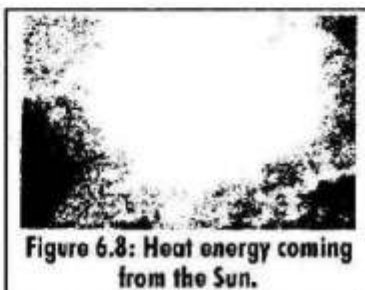



Figure 6.8: Heat energy coming from the Sun.

3. Electrical energy:

Electricity is one of the widely used form of energy.

Electrical energy can be supplied through wires, easily to any desired place.

Sources of electrical energy:

Electrical energy can get from batteries and electric generators.

Most of the electric generators are run by hydro power, thermal or nuclear power.

Example: Most of the things of our daily use need electrical energy for their operation.

Figure 6.9: Most of the things of our daily use need electrical energy for their operation.

4. Sound Energy: Sound is a form of energy.

Prouduction of sound: Sound is produced when a body vibrates.

Examples: Following instruments produce sound.

(i) Vibrating diaphragm of a drum.
(ii) Vibrating strings of a sitar.
(iii) Vibrating air column of wind instruments such as flute pipe etc.
(iv) When a door is knocked, a sound is produced.

Figure 6.10: Sound energy

5. Light energy: Light is an important form of energy.

Sources of light energy:

⇒ Sun is the great source of light energy.

⇒ Light energy can be obtained from candles, electric bulbs, fluorescent tubes and also by burning fuel.

Importance of light energy:

⇒ Plants produce food in the presence of light.

⇒ Light is necessary to see things. Light is needed during night also to see things.

Figure 6.11: Light is needed during night also

6. Chemical Energy:

Chemical energy is present in food, fuels and in other substances. The energy is released from these substances during chemical reactions.

Figure 6.12: (a) Cooking stove with compressed gas cylinder (b) sectional view of electrical cell.

Energies produced by burning process:

The burning of wood, coal or natural gas in air is a chemical reaction which releases energy as heat and light.

Source of electric energy: Electric energy is obtained from electric cells and batteries as a result of chemical reaction between various substances present in them.

Importance of food for animals:

Animals get heat and muscular energy from the food they eat.

7. Nuclear energy:

Nuclear energy is the energy released in the form of nuclear radiations in addition to heat and light during nuclear fission and fusion reactions.

DO YOU KNOW?

Our body gets energy stored in the food we take to perform00 various activities.

Nuclear reactors are source of electrical energy:

Heat energy released in nuclear reactors is converted into electrical energy.

So, nuclear reactor is a source of electrical energy.

DO YOU KNOW?

A nuclear power plant uses the energy released in nuclear reactor such as fission to generate electric power.

Reason of solar energy:

The energy coming from the Sun for the last billions of years is the result of nuclear reactions taking place on the Sun.

6.6 Interconversion of energy

Q6. What do you mean by interconversion of energy? Explain with examples.

Ans: Energy cannot be destroyed however it can be converted from one form to another form. But total energy of the system at any time remains constant.

Example # 1: By rubbing hands quickly, these will be warmed. Its mean in rubbing hands muscular energy is used and as a result heat is produced.

In this process of rubbing hands, mechanical energy is converted into heat energy.

Example # 2: The given figure shows interconversion of kinetic energy into potential energy and potential energy into kinetic energy.

Potential energy
Energy in
Energy out
Kinetic energy
Kinetic energy

Figure 6.13: Interconversion of kinetic energy into potential energy and potential energy into kinetic energy.

At the surface of the Earth, the potential energy of the body will be zero while at this point its kinetic energy is maximum.

At the highest point, the kinetic energy of the body will be zero while its potential energy is maximum at this point.

Interconversion of energy in nature:

Processes in nature are the results of energy changes.

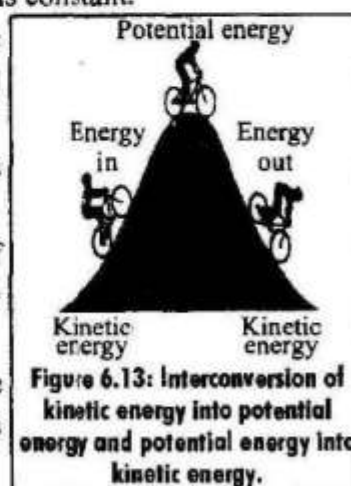
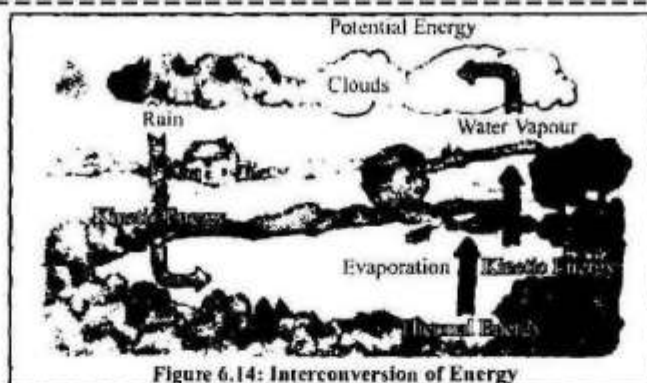



Figure 6.14: Interconversion of Energy

Solar energy absorbed by oceans: Some of the heat energy from the Sun is absorbed by water in the oceans. This increases the thermal energy.

Function of thermal energy in oceans:

Thermal energy causes water to evaporate from the surface to form water vapours.

Formation of clouds: As these water vapours rise up, they form clouds.

As these water vapours in the clouds cool down, they form water drops. These water drops fall down as rain.

Potential energy changes into kinetic energy:

Potential energy changes into kinetic energy as the rain falls. This rain water may reach a lake or a dam.

Kinetic energy changes into thermal energy:

As the rain water flows down, its kinetic energy changes into thermal energy while parts of the kinetic energy of flowing water is used to wash away soil particles of rocks known as soil erosion.

During the inter-conversion of energy from one form to other forms, the total energy at any time remains constant.

DO YOU KNOW?

A pole vaulter uses a flexible vaulting pole made of special material. It is capable to store all the vaulter's kinetic energy while bending in the form of potential energy. The vaulter runs as fast as possible to gain speed. The kinetic energy gained by the vaulter due to speed helps him/her to rise up as the vaulter straightens. Thus he attains height as the pole returns the potential energy stored by the vaulter in the pole.

6.7 Major Sources of Energy

Q7. What do you know about sources of energy? Write an extensive note.

Ans: The energy which is used by us comes from the Sun, wind and water power etc.

Sun: Sun is the greatest and main source of energy. Actually, all of our energy comes directly or indirectly from the Sun.

Basic sources of energy: There are basically two sources of energy.

(1) Fossil Fuels (2) Nuclear Fuels

(1) Fossil Fuels: Fossil fuels are used by us to run industry and transport such as coal, oil and gas. These are also used to heat our houses.

Hydrocarbons:

Fossil fuels are usually called hydrocarbons (compounds of carbon and hydrogen).

Reaction of hydrocarbons:

When hydrocarbons are burnt, they combine with oxygen from the air.

The carbon becomes carbon dioxide, hydrogen becomes hydrogen oxide called water, while energy is released as heat.

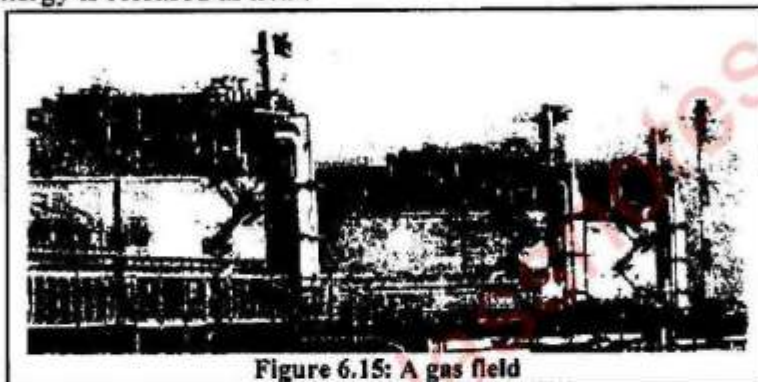



Figure 6.15: A gas field

(a) In case of coal:

In case of coal reaction will take place as.

Carbon + Oxygen ⟶ Carbon dioxide + heat energy.

(b) In case of oil and gas:

In case of oil and gas, reaction will take place as

Hydrocarbon+oxygen → carbon dioxide+water+heat energy

Figure 6.16: Coal

Figure 6.17: An oil field

Non-renewable resources: The fossil fuels took millions of years for their formation. So, they are known as non-renewable resources.

Usage rate of fossil fuels: Fossil fuels are used by us at a very fast rate. Their use is increasing day by day to meet our energy needs.

If we continue to use these fossil fuels at a present rate, these will soon be exhausted.

Problems related with the exhausted supply of fossil fuels:

⇒ Once the supply of fossil fuels is exhausted, the world would face serious energy crisis.

⇒ Fossil fuels would not be able to meet our future energy demands.

⇒ Exhausted supply of fossil fuels would cause serious social and economical problems for countries like us.

Method to save the fossil fuels: To save the fossil fuels, these must be used wisely by us and at the same time, we should develop new energy sources for our future survival.

Harmful waste products released by fossil fuels:

Many harmful waste products are released by fossil fuels. These wastes include carbon mono-oxide and other harmful gases, which pollute the environment.

Problems related with harmful products of fossil fuels:

Harmful products of fossil fuels cause serious health problems such as headache, tension, nausea, allergic reactions, irritation of eyes, nose and throat.

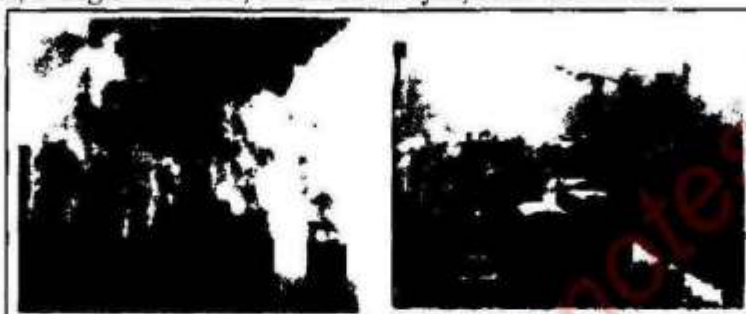



Figure 6.18: Pollution due to burning of fossil fuel

Long exposure of these harmful gases may cause asthma, lungs cancer, heart diseases and even damage to brain, nerves and other organs of our body.

2. Nuclear fuels: Nuclear fuels are also source of energy.

Nuclear fission: In nuclear power plants, energy is obtained by using Uranium.

The process taking place in nuclear reactors is known as nuclear fission.

Nuclear fission reaction is a source of energy:

During fission reaction, the heavy nucleus of an atom splits up into smaller parts releasing a large amount of energy. Nuclear power plants give out a lot of nuclear radiations and vast amount of heat.

Figure 6.19: Nuclear fuel pallets used in nuclear reactors.

Disadvantages of nuclear reactions:

⇒ Nuclear fuels has dangerous wastes.
⇒ No complete safe method has yet been discovered for their disposal
⇒ Nuclear power plants give off a lot of waste heat, which can be harmful to the environment.

Q8. What are the renewable energy sources. Write a detail and extensive note on them.

Ans: Renewable energy sources: The energy sources which will not run out like coal, oil and gas and can be used again and again are called renewable energy sources. Sunlight and water power are the renewable sources of energy.

1. Energy from water:

Energy from water power is very cheap. Water power is becoming more popular.

Construction of dams:

Dams are being constructed at suitable locations in different parts of the world.

Advantages of dams: Dams are used for many purposes.

(1) Dams help to control floods by storing water.

(2) The water stored in dams is used for irrigation and also to generate electrical energy without creating much environmental problems.

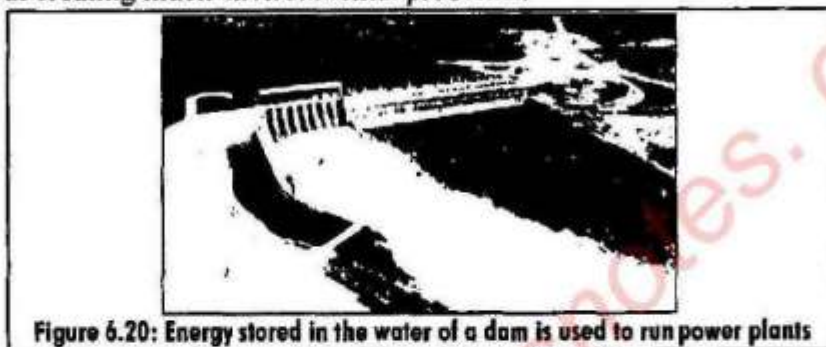



Figure 6.20: Energy stored in the water of a dam is used to run power plants

2. Energy from the Sun: Solar energy is the energy coming from the Sun. The energy coming up from the Sun is used directly and indirectly.

Importance of solar energy:

All the lives on the Earth are dependent on the Sun for all their food and fuels.

Advantages of solar energy:

⇒ Sunlight does not pollute the environment in any way.

⇒ The Sunrays are the ultimate source of life on Earth.

⇒ If we find a suitable method to use a fraction of the solar energy reaching the Earth, then it would be enough to fullfil our energy requirement.

Solar House Heating: It is an important way to use solar energy.

The use of solar energy is not new. However, its use in houses and offices as well as for commercial industrial purposes is quite recent.

Parts of solar house heating:

Complete solar house heating systems are successfully used in areas with a minimum amount of sunshine in winter:

Figure 6.21: A Solar house heating system

A heating system consists of.

- A collecter
- A storage device
- A distribution system

Above figure shows a solar collector made of glass panels over blank metal plates.

Function of blank metal plates: The blank metal plates absorb the Sun's energy which heats a liquid flowing in the pipes at the back of the collector.

Use of hot water: Hot water obtained by the solar house can be used for cooking, washing and for heating the buildings.

Purposes of solar energy: Solar energy is used in solar cookers, solar distillation plants, solar power plants etc.

Solar cells: Solar energy can also be converted directly into electricity by solar cells.

Figure 6.22: A solar car

Photo cells: A solar cell also called photo cell. It is made from silicon wafers.

Principle of solar cell: When sunlight falls on a solar cell, it converts the light directly into electrical energy.

Uses of solar cell:

⇒ Solar cells are used in calculators, watches and toys.

⇒ Large number of solar cells are wired together to form solar panels.

Uses of solar panels:

⇒ Solar panels can provide power to telephone booths, light houses and scientific research centres.

⇒ Solar panels are also used to power satellites.

Figure 6.23: A solar panel fixed at the roof of a house

Importance of use of solar energy in future:

If scientists could find an efficient and inexpensive method to use solar energy, then the people would get clean, limitless energy as long as the Sun continues to shine.

3. Wind energy: Wind has been used as a source of energy for centuries.

Importance of wind energy:

⇒ Wind energy has powered sailing ships across the oceans.

⇒ Wind energy has been used by windmills to grind grain and pump water.

⇒ More recently, wind power is used to turn wind turbines.

Figure 6.24: Wind turbines

Operation of power plant: When many wind machines are grouped together on wind farms, they can generate enough power to operate a power plant.

Usage of wind energy in United States: In the United States, some wind farms generate more than 1300 MW of electricity in a day.

Usage of wind energy in Europe: In Europe, many wind farms routinely generate one hundred or more megawatts electricity a day.

4. Geothermal Energy: In some parts of the world, the Earth provides us hot water from geysers and hot springs.

Definition: There is hot molten part, deep in the Earth called magma. Water reaching close to the magma changes to steam due to the high temperature of magma. This energy is called geothermal energy.

Process to obtain geothermal energy:

Places, where magma is not very deep, geothermal well can be built by drilling deep near hot rocks.

Water is then pushed down into well. The rocks quickly heat the water and change it into steam.

It expands and moves up to the surface.

Figure 6.25: A geothermal power station

The steam can be piped directly into houses and offices for heating purposes or it can be used to generate electricity.

5. Energy from biomass:

Biomass is plant or animal wastes that can be burnt as fuel.

Other forms of biomass are garbage, farm wastes, sugarcane and other plants.

Advantages of biomass energy:

(a) The energy which is obtained by biomass, is used to run power plants.

(b) Many industries that use forest products get half of their electricity by burning bark and other wood wastes.

(c) Methane obtained from biomass is used to generate electricity.

Figure 6.26: A biomass plant using animal dung

Problems related with biomass energy:

Biomass can serve as another source of energy, but problems are there in its use.

When animal dung, dead plants and dead animals decompose, they give off a mixture of methane and carbon dioxide which is considered as a pollutant.

Q9. How will you define and explain mass-energy equation?

Ans: Einstein predicted the interconversion of matter and energy.

Einstein's view:

According to Einstein, a loss in the mass of a body provides a lot of energy.

This happens in nuclear reactions.

Einstein's equation: The relation between mass (m) and enregy (E) is given by Einstein's mass energy equation.

$$E = mc^2$$

Here c is the speed of light. Its value is ($3\times10^8\ ms^{-1}$).

Matter is a source of energy: Einstein's equation shows that tremendous amount of energy can be obtained from small quantity of matter.

It appears that matter is a highly concentrated form of energy.

Application of Einstein's energy in nuclear power plant:

The process of getting energy from our nuclear power plants is based on the Einstein's equation.

Relation of fission reaction with solar energy:

The process of fission reaction is taking place on the Sun and on the stars for the last millions of years. Only a very small fraction of the Sun's energy is reaching the Earth. This very small fraction of the Sun's energy is responsible for life on the Earth.

Q10. How electricity can be obtained from fossil fuels? Write brief note.

Ans: Electricity is used in houses, offices, schools, business centres, factories and farms. Electricity can be obtained by different ways.

Electricity from fossil fuels:

Most of the electricity is obtained using fossil fuels such as oil, gas and coal.

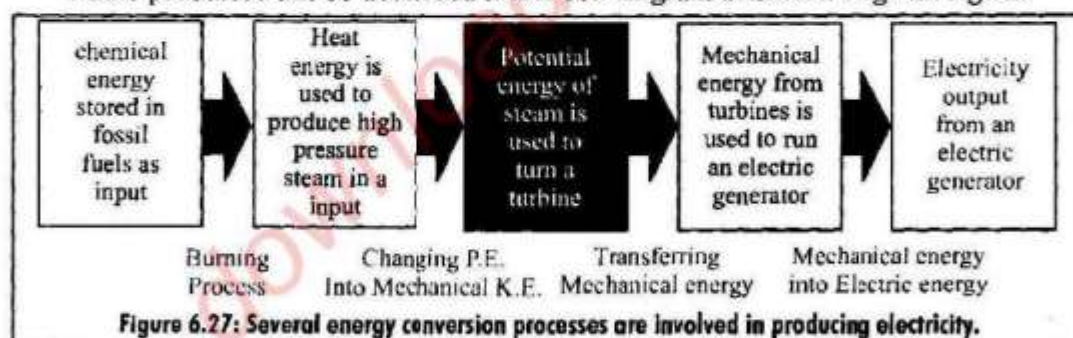
Burning of fossil fuels:

Fossil fuels are burnt in thermal power stations to produce electricity.

Energy conversion processes to obtain electricity from fossil fuels:

Various energy conversion processes are involved to obtain electricity from fossil fuels.

These processes can be described in a block diagram as shown in given figure.

Figure 6.27: Several energy conversion processes are involved in producing electricity.

Q11. How energy and environment are related with each other? Write a detail note. OR

How environmental problems are related with energy. How these problems can be controlled?

Ans: Environmental problems such as pollution that consist of noise, air pollution and water pollution may arise by using different sources of energy such as fossil fuels and nuclear energy.

Pollution: Pollution is the change in the quality of environment that can be harmful and unpleasant for living things.

Thermal pollution:

A temperature rise in the environment that disturbs life is called thermal pollution.

Effect of thermal pollution: Thermal pollution upsets the balance of life and endangers the survival of many species.

Air pollution: Air pollution has very bad impact on environment.

Air pollutants, are unwanted and harmful.

Air pollutants released from natural processes:

⇒ Natural processes such as volcanic eruptions, forest fires and dust storms add pollutants to the air.

⇒ These pollutant, rarely build up to harmful levels and are very dangerous for health.

Air pollutants released from human activities:

The burning of fuel and solid wastes in homes, automobiles and factories releases harmful amount of air pollutants.

Waste heat produced by power plants:

All power plants produce waste heat, but fission plants produce the most.

Impact of heat in environment: The heat released by power plants into a lake, a river or an ocean upsets the balance of life in them.

Pollutants released by power plants:

⇒ Power plants release a large amount of carbon dioxide in environment.

⇒ Nuclear power plants do not produce carbon dioxide but produce dangerous radioactive wastes as pollutants.

Methods used to control pollution:

In many countries governments have passed laws to control air pollution. Some of these laws limit the amount of pollution that is released by power plants, factories and automobiles.

Use of catalytic convertors: To reduce or convert some polluting gases for automobiles, new cars have catalytic convertors.

Use of lead free petrol:

The use of lead free petrol has greatly reduced the amount of lead in the air.

Formation of engine which does not use diesel and petrol:

Engineers are working to improve new kinds of car engines that use electricity or energy sources other than diesel and petrol.

Use of public transport: Sharing rides and using public transportation are the ways to reduce the number of automobiles in use. Due to this less fuel and energy is used and less pollutants are released in the environment.

Contributions of individual communities and indviduals to reduce pollution.

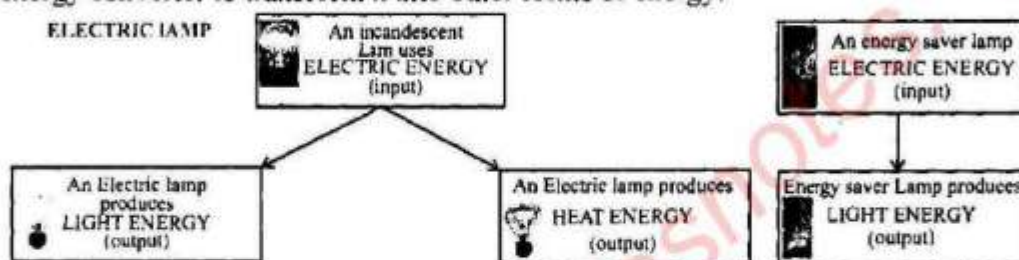
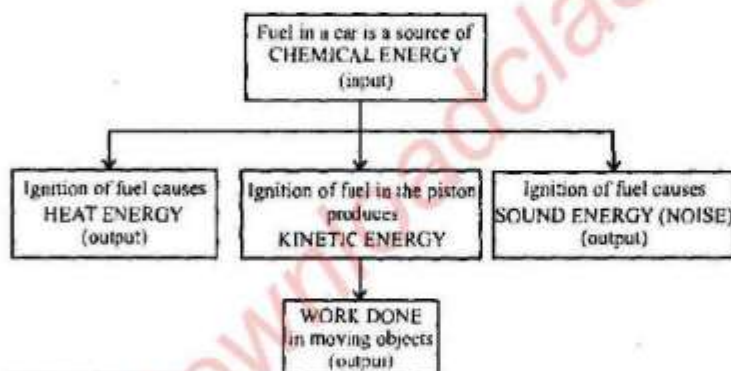
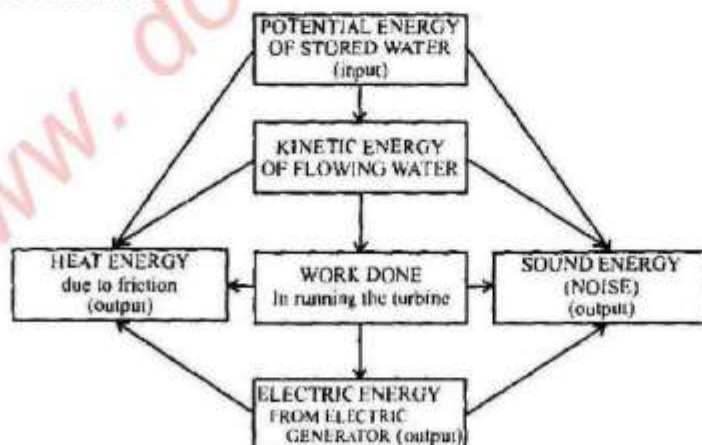
⇒ Many individual communities have laws which protect their areas from pollution.

⇒ Individuals can help to control air pollution simply by reducing the use of cars and other machines that burn fuel.

Q12. Draw a simple energy flow diagram of a converter.

Ans: In an energy converter, a part of the energy taken (used up) by the system is converted into useful work.

Remaining part of the energy is dissipated as heat energy, sound energy (noise) into the environment.

Energy flow diagram: Energy flow diagrams given below show the energy taken up by an energy converter to transform it into other forms of energy.

6.8 Efficiency

Q13. What is the importance of energy for a machine. How input, out put, efficiency and percentage efficiency of a machine can be defined?

Ans: Energy is necessary for a machine to perform its functions properly.

Energy of humans: Human machine also needs energy to do a variety of work. Human takes food to fulfil the energy needs of their body.

Use of electric motor: Electric motor is used to pump water, to blow air to wash clothes, to drill holes etc.

Input: The energy given to a system is called input.

Figure 6.28: An electric drill

Output: The work which is done by the machine is called output.

Efficiency: Efficiency of a system is the ratio of required form of energy obtained from a system as output to the total energy given to it as input.

Formula of efficiency: Efficiency can be obtained by following formula.

$$\text{Efficiency} = \frac{\text{required form of output}}{\text{Total input energy}}$$

Percentage efficiency: Percentage efficiency can be obtained by following formula.

$$\%\ \text{Efficiency} = \frac{\text{required form of output}}{\text{total input energy}} \times 100$$

Ideal system:

Ideal system is that which gives an output equal to the total energy used by it.

The efficiency of an ideal system is 100%. People have tried to design a working system that would by 100 % efficient. But practically such a system does not exist.

Real system: A real system is that which gives an output less than to the total energy used by it. Every system meets energy losses due to friction that causes heat, noise etc.

These are not the useful forms of energy and go waste.

This means we cannot utilize all the energy given to a working system. In the real system the energy in the required form obtained from a working system is always less than the energy given to it as input.

Example 6.5 ***A cyclist does 12 joules of useful work while pedalling his bike from every 100 joules of food energy which he takes. What is his efficiency?***

Solution: Useful work done by the cyclist = 12 J

Energy used by the cyclist = 100J

$$\text{Efficiency} = \frac{12\text{J}}{100\text{J}}$$

$$= 0.12$$

or % efficiency $= 0.12 \times 100 = 12\ \%$

The efficiency of the cyclist is 12 %.

ADDITIONAL INFORMATION Efficiencies of some typical devices/machines			
Energy Input	Device or Machine	Useful Work done	%Efficiency
100J	Electric Lamp	5 J	5 %
100J	Petrol Engine	25 J	25 %
100J	Electric Motor	80 J	80 %
100J	Electric Fan	55 J	55 %
100J	Solar Cell	3 J	3 %

6.9 Power

Q14. What is power? Give example write its formula and unit.

Ans: Power: Power is defined as the rate of doing work. OR

The quantity that tells us the rate of doing work is called power.

Example: Two persons have done equal work, one took, one hour to complete it, and the other completed it in five hours. No doubt, both of them have done equal work but they differ in the rate at which work is done. First person has high power because it has done its job in a short time as compare to second.

Formula:

$$\text{Power} = \frac{\text{Work done}}{\text{time taken}}$$

or $$P = \frac{\text{Work}}{\text{time}}$$

Scalar quantity:

Power is a scalar quantity, because it needs magnitude only for complete description.

Unit of power:

SI unit of power is watt (W).

Definition of watt:

The power of a body is one watt if it does work, at the rate of 1 joule per second (1Js^{-1}).

Bigger units of power:

Bigger units of power are kilowatt (k W), megawatt (M W) etc.

$1\text{kW} = 1000\ \text{W} = 10^3\ \text{W}$

$1\text{MW} = 1000000\ \text{W} = 10^6\ \text{W}$

1 horse power $= 1\text{hp} = 746\ \text{W}$

Example 6.6 ***A man M_1 takes 80 s in lifting a load of 200 N through a height of 10m. While another man M_2 takes 10 s in doing the same job. Find the power of each.***

Solution: F = 200 N

S = 10m

Time taken by man M_1 = $t_1 = 80$ s

Time taken by man M_2 = $t_2 = 10$s

As work done = F × S

= 200 N × 10 m = 2000 J

Power of man M_1 = $\frac{\text{Work}}{t_1}$

= $\frac{2000\text{J}}{80\text{s}} = 25\text{ Js}^{-1}$ = 25 watts

and Power of man M_2 = $\frac{\text{Work}}{t_2}$

= $\frac{2000\text{J}}{10\text{s}} = 200\text{ Js}^{-1}$ = 200 watts

Thus the power of M_1 is 25 watts and that of M_2 is 200 watts.

Example 6.7 ***Calculate the power of a pump which can lift 70 kg of water through a vertical height of 16 metres in 10 seconds. Also find the power in horse power.***

Solution:

Mass of water m = 70 kg

Height S = 16m

Time taken t = 10s

Force required F = w = mg

= 70kg × 10 ms^{-2}

= 700 N

Work done W = F × S

or W = 700 N × 16m

W = 11200 J

Power = $\frac{W}{t}$

P = $\frac{11200\text{J}}{10\text{s}} = 1120\text{ Js}^{-1}$

= 1120 watts

As 1hp = 746 watts

$$P = \frac{1120 \text{ watts}}{746 \text{ watts}} \text{hp}$$

$$P = 1.5 \text{ hp}$$

Thus, power of the pump is 1.5 hp.

SUMMARY

- Work is said to be done when a force acting on a body moves it in the direction of the force.
  - Work = FS
  - SI unit of work is joule (J).
- When we say that a body has energy, we mean that it has the ability to do work. SI unit of energy is also joule, the same as work.
- Energy exists in various forms such as mechanical energy, heat energy, light energy, sound energy, electrical energy, chemical energy and nuclear energy etc. Energy from one form can be transformed into another.
- The energy possessed by a body due to its motion is called kinetic energy.
- The energy possessed by a body due to its position is called potential energy.
- Energy cannot be created nor destroyed, but it can be converted from one form to another.
- Processes in nature are the result of energy changes. Heat from the Sun causes water of oceans to evaporate to form clouds. As they cool down, they fall down as rain.
- Einstein predicted the interconversion of matter and energy by the equation $E = mc^2$.
- Fossil fuels are known as non-renewable resources because it took millions of years for them to attain the present form.
- Sunlight and water power are the renewable resources of energy. They will not run out like coal, oil and gas.
- Environmental problems such as polluting emission consisting of noise, air pollution and water pollution may arise by using different sources of energy such as fossil fuels, nuclear energy.
- The ratio of the useful work done by a device or machine to the total energy taken up by its is called its efficiency.
- Power is defined as the rate of doing work.
- The power of a body is one watt which is doing work at the rate of one joule per second.

SOLVED QUESTIONS

6.1 Encircle the correct answer from the given choices:

(i) The work done will be zero when the angle between the force and the distance is:
(a) 45° (b) 60° (c) 90° (d) 180°

(ii) If the direction of motion of the force is perpendicular to the direction of motion of the body, then work done will be:
(a) Maximum (b) Minimum (c) Zero (d) None of above

(iii) If the velocity of a body becomes double, then its kinetic energy will:
(a) remain the same (b) become double
(c) become four times (d) become half

(iv) The work done in lifting a brick of mass 2 kg through a height of 5 m above ground will be:
(a) 2.5J (b) 10J (c) 50J (d) 100J

(v) The kinetic energy of a body of mass 2 kg is 25J. its speed is:
(a) 5 ms^{-1} (b) 12.5 ms^{-1} (c) 25 ms^{-1} (d) 50 ms^{-1}

(vi) Which one of the following converts light energy into electrical energy?
(a) electric bulb (b) electric generator (c) Photo cell (d) Electric cell

(vii) When a body is lifted through a height h, the work done on it appears in the form of its:
(a) kinetic energy (b) potential energy
(c) elastic potential energy (d) geothermal energy

(viii) The energy stored in coal is:
(a) heat energy (b) kinetic energy (c) chemical energy (d) nuclear energy

(ix) The energy stored in a dam is:
(a) electric energy (b) potential energy (c) kinetic energy (d) thermal energy

(x) In Einstein's mass-energy equation, c is the:
(a) speed of sound (b) speed of light (c) speed of electron (d) speed of Earth

(xi) Rate of doing work is called:
(a) energy (b) torque (c) power (d) momentum

Ans: (i) 90° (ii) Zero (iii) become four times (iv) 100J
(v) 5 ms^{-1} (vi) Photo cell (vii) potential energy (viii) chemical energy
(ix) potential energy (x) speed of light (xi) power

6.2 Define work. What is its SI unit?

Ans: Work: Work is said to be done when a force acting on a body displaces it in the direction of the force.

Work = Force × distance

SI unit of work: SI unit of work is joule (J)

Definition of joule: The amount of work is one joule when a force of one newton displaces a body through one metre in the direction of force.

6.3 When does a force do work? Explain.

Ans: When a force acting on a body displaces it through some distance S in the direction of force as shown in the given figure, it does work on a body.

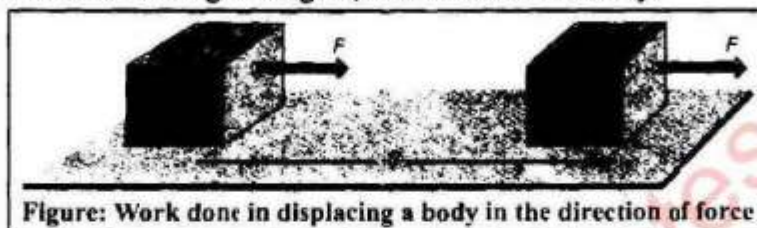
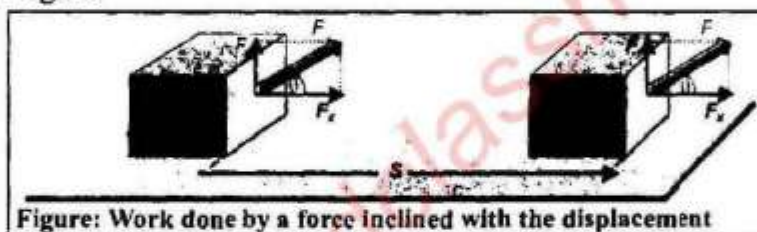



Figure: Work done in displacing a body in the direction of force

Sometimes the force and displacement do not have the same direction such as shown in figure.

Figure: Work done by a force inclined with the displacement

In this case, force **F** is making an angle (θ) with the surface on which body is moved. Resolving **F** into its perpendicular components F_x and F_y as;

$$F_x = F\cos\theta$$

$$F_y = F\sin\theta$$

In case when force and displacement are not parallel then only the x-component F_x parallel to the surface causes the body to move on the surface and the y-component F_y.

Hence $W = F \times S$

$$W = (F\cos\theta)S$$

$$W = FS\cos\theta$$

6.4 Why do we need energy?

Ans: Energy is used by us to perform many activities of life.

Energy is necessary for running and walking for humans.

6.5 Define energy, give two types of mechanical energy.

Ans: Energy: A body possesses energy if it is capable to do work.

Types of mechanical energy: Mechanical energy has two following types.

(i) Kinetic energy. (ii) Potential energy.

(i) Kinetic energy: The energy possessed by a body due to its motion is called its

kinetic energy.

Formula: $K.E = \frac{1}{2}mv^2$

Unit of kinetic energy is joule (J).

(ii) Potential energy: The ability of a body to do work due to its position is known as its potential energy.

Formula: $P.E = mgh$.

Unit of potential energy is joule (J).

6.6 Define K.E and derive its relation.

Ans: See Q # 3

6.7 Define potential energy and derive its relation.

Ans: See Q # 4

6.8 Why are fossil fuels called non-renewable form of energy?

Ans: The fossil fuels take millions of years for their formation. So these are known as non-renewable resources.

6.9 Which form of energy is most preferred and why?

Ans: Solar energy is most preferred energy because Sunlight does not pollute the environment in any way.

Solar energy reaching Earth is thousand times more than the energy consumption of mankind.

6.10 How is energy converted from one form to another? Explain.

Ans: See Q # 6.

6.11 Name any five devices that convert electrical energy into mechanical energy.

Ans: Washing machine:

⇒ Juicer ⇒ Electric motor
⇒ Electric grinder ⇒ Electric spinner

6.12 Name a device that converts mechanical energy into electrical energy.

Ans: Generator is a device that converts mechanical energy into electrical energy.

6.13 What is meant by the efficiency of a system?

Ans: Efficiency of a system is the ratio of required form of enregy obtained from a system as output to the total energy given to it as input.

6.14 How can you find the efficiency of a system?

Ans: Efficiency of a system can be found out by following formula.

$$\text{Efficiency} = \frac{\text{required form of output}}{\text{total input energy}}$$

$$\%\ \text{Efficiency} = \frac{\text{required form of output}}{\text{total input energy}} \times 100$$

6.15 What is meant by the term power?

Ans: Power is defined as the rate of doing work.

$$\text{Power} = \frac{\text{work done}}{\text{time taken}}$$

$$P = \frac{W}{t}$$

The unit of power is watt. Bigger units of power are kilowatt (kW), megawatt (MW) etc.

6.16 Define watt.

Ans: The power of a body is one watt if it does work at the rate of 1 joule per second ($1 Js^{-1}$).

SOLVED PROBLEMS

6.1 A man has pulled a cart through 35 m applying a force of 300 N. Find the work done by the man.

Data: Distance = S = 35 m
Force = F = 300N

Required: Work done = ?

Formula: $W = F \times S$
Work = Force × distance

Solution: By putting the values in the formula amount of work can be found out.

$W = F \times S$

$W = 35 \times 300$

$\boxed{W = 10500 J}$

Answer: The required work done by the man is 10500J.

6.2 A block weighing 20 N is lifted 6 m vertically upward. Calculate the potential energy stored in it.

Data: Force = Weight = w = 20 N
Distance = S = 6m

Required: Potential energy = P.E ?

Solution: In this potential energy is equal to the work done of the body.

P.E = Work done = Force × distance

$= 20 \times 6$

$\boxed{P.E = 120 J}$

Answer: The potential energy of the body is 120J.

6.3 A car weighing 12 kN has speed of 20 ms⁻¹. Find its kinetic energy.

Data: Weight = w = 12 kN

Speed = v = 20 ms^{-1}

Required: Kinetic energy = K.E = ?

Formula: $K.E = \frac{1}{2}mv^2$

Solution: Value of K.E can be found out by using above formula

Weight = 12 kN

As we know;

$$w = mg$$

$$\frac{w}{g} = m$$

$$\frac{12k}{10} = m$$

$$m = 1.2 \text{ kg}$$

$$K.E = \frac{1}{2}mv^2$$

$$K.E = \frac{1}{2}(1.2)(20)^2$$

$$K.E = \frac{1}{2}(1.2)(400)$$

$$K.E = \frac{1}{2}(480)$$

$$\boxed{K.E = 240 \text{ J}}$$

Answer: The required K.E of the car is 240 kJ.

6.4 A 500 g stone is thrown up with a velocity of 15ms⁻¹. Find its

(i) P.E. at its maximum height

(ii) K.E. when it hits the ground

Given: Mass of stone = m = 500g = 0.5kg

Initial velocity of stone = v_i = 15 ms^{-1}

Final velocity of stone = v_f = 0 ms^{-1}

Required: (i) P.E. at its maximum height = ?

(ii) K.E. when it hits the ground = ?

Solution: To find the value of h:

$v_i = 15 \text{ ms}^{-1}$

$v_f = 0 \text{ ms}^{-1}$

$g = -10 \text{ ms}^{-2}$

$S = h = ?$

using 2gh = $2gh = v_f^2 - v_i^2$

$2(-10)\,h = 0^2 - 15^2$

$-20\,h = 0 - 225$

$h = \frac{225}{20}$

$\boxed{h = 11.25\,m}$

Potential Energy:

$P.E. = mgh$

$P.E. = 0.5 \times 10 \times 11.25$

$\boxed{P.E = 56.25\,J}$

Downward Motion of stone:

$v_i = 0$, $h = 11.25$ m, $v_f = ?$

using

$2gh = v_f^2 - v_i^2$

$2 \times 10 \times 11.25 = v_f^2 - 0^2$

$225 = v_f^2$

$V_f = 15\ ms^{-1}$

Kinetic Energy:

$K.E. = \frac{1}{2}mv^2$

$= \frac{1}{2} \times 0.5 \times 225$

$K.E. = 56.25\ J$

Thus, Potential energy of stone at its maximum height is 56.25 J.

And,

Kinetic energy, when it hits the ground is 56.25 J.

6.5 ***On reaching the top of a slope 6 m high from its bottom, a cyclist has a speed of 1.5 ms^{-1}. Find the kinetic energy and the potential energy of the cyclist. The mass of the cyclist and his bicycle is 40 kg.***

Data: Height = h = 6m

Speed = v = 1.5 ms^{-1}

Mass = m = 40 kg

Gravitational acceleration = g = 10ms^{-2}

Required: Kinetic energy = K.E = ?

Potential energy = P.E = ?

Formula:

(i) $K.E = \frac{1}{2}mv^2$

(ii) $P.E = mgh$

Solution: By using above formulas the value of K.E and P.E can be found:

(i) $K.E = \frac{1}{2}mv^2$

$K.E = \frac{1}{2}(40)(1.5)^2 = \frac{1}{2}(\overset{20}{40})(2.25)$

$= (20)(2.25)$

$\boxed{K.E = 45J}$

(ii) $P.E = mgh$

$P.E = (40)(10)(6)$

$P.E = 2400J$

$\boxed{\text{Potential Energy} = P.E = 2400J}$

Answers: (i) The required kinetic energy (K.E) is equal to 45J.

(ii) The required potential energy (P.E) of the cyclist is 2400 J.

6.6 A motor boat moves at a steady speed of 4 ms^{-1}. Water resistance acting on it is 4000 N. Calculate the power of its engine.

Data: Speed = v = 4ms^{-1}

Force = F = 4000 N

Required: P = Power = ?

Formula:

$\text{Power} = \frac{W}{t} \longrightarrow (1)$

As we know:

$W = F \times S$

But $S = V \times t$

$W = F \times V \times t$

Put in 1

$P = \frac{F \times V \times t}{t}$

$P = F \times V$

By putting values, we get

$P = 4000\,N \times 4ms^{-1}$

$P = 16000\,W$

$P = 16 \times 1000\,W$

$\boxed{P = 16\,kW}$

Answer: The required power of the engine is 16 kW.

6.7 *A man pulls a block with a force of 300 N through 50 m in 60 s. Find the power used by him to pull the block.*

Data: Force = F = 300N
Distance = S = 50 m
Time = t = 60s

Required: Power = P = ?

Formula:

$$\text{Power} = \frac{\text{work}}{\text{time}} \qquad \because \text{Work} = F \times S$$

Solution: By putting the values in this formula, value of Power can be found out.

$$P = \frac{F \times S}{t}$$

$$P = \frac{(300N)(50m)}{(60s)}$$

$$\boxed{P = 250 \text{ Watt}}$$

Answer: The required power used by the man to pull the block is 250W.

6.8 *A 50 kg man moves 25 steps up in 20 seconds. Find his power, if each step is 16 cm high.*

Ans: Mass of man = m = 50 kg
Time = t = 20 sec
Height of each step = d = 16 cm
$= 16 \times 10^{-2}$m
Number of steps = 25
Power = P = ?

$$\text{Power} = \frac{\text{work}}{\text{time}} = \frac{W}{t} \qquad (I)$$

But:

$$\text{Work} = W = F \times S \quad (II)$$

And:

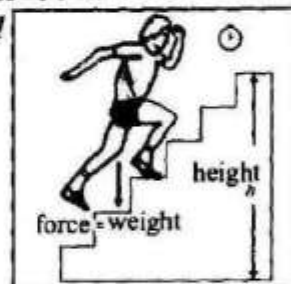
$$S = 16 \times 10^{-2} \times 25 = 4m$$

Put in (II)

$$W = mg \times S$$
$$= 50 \times 10 \times 4$$
$$W = 2000$$

Put in (I)

$$P = \frac{2000}{20}$$

$$\boxed{P = 100 \text{ W}}$$

Thus, Required power of a man is 100 watt.

6.9 Calculate the power of a pump which can lift 200 kg of water through a height of 6 m in 10 seconds.

Data: Mass = m = 200 kg

height = h = 6m

Time = t = 10 seconds

Required: Power = P = W = ?

Formula:

$$\text{Power} = \frac{\text{work}}{\text{time}} = \frac{w}{t}$$

Solution: In this case work done is equal to the potential energy of body.

$$W = P.E = mgh$$

$$= (200)(10)(6)$$

$$W = P.E = 12000\text{ J}$$

By putting the values, power can be calculated as,

$$\text{Power} = \frac{12000}{10}$$

$$\boxed{\text{Power} = 1200\text{ watts}}$$

Answer: The required power of a pump which can lift 200 kg of water through a height of 6m is 1200 watts.

6.10 An electric motor of 1hp is used to run water pump. The water pump takes 10 minutes to fill an overhead tank. The tank has a capacity of 800 litres and height of 15 m. Find the actual work done by the electric motor to fill the tank. Also find the efficiency of the system.

(Density of water = 1000kg m^{-3})

(Mass of 1 litre of water = 1kg)

Solution: Data:

Power of motor = 1hp = 746 W

Time = t = 10 min

= 10 × 60 sec

= 600 sec.

Tank capacity = m = 800 kg

Height = h = 15m

Work done = W = ?

Efficiency = ?

Formula:

$$P = \frac{W}{t}$$

$$W = P \times t$$

$$= 746 \times 600\ J$$

$$W = 447600\ J$$

This is energy given by motor to fill the tank. Now the work done to fill the tank is P.E.

Hence, Used

$$W = P.E. = mgh$$

$$W = 800 \times 10 \times 15$$

$$W = 120,000\ J$$

Hence the work done is 120000J

Now,

$$\text{Efficiency} = \frac{\text{Work done}}{\text{Energy}}$$

$$\text{Efficiency} = \left(\frac{120000}{447600} \times 100\right)\%$$

$$E = 26.8\ \%$$

Hence the efficiency is 26.8%,

OBJECTIVE TYPE QUESTIONS (MCQ'S+SHORT ANSWER) FROM PREVIOUS ANNUAL PAPERS OF ALL SECONDARY BOARDS
(LAHORE, GUJRANWALA, FAISALABAD, MULTAN, SAHIWAL, SARGODHA, RAWALPINDI, D.G. KHAN And BAHAWALPUR)

6.1+6.2	Work+Energy
6.3	Kinetic Energy

☆ **Tick the correct answer.**

1. **The work done in lifting a brick of mass 2 kg through a height of 5m above the ground will be:** **(LHR. GI)**
   (A) 2.5J (B) 10J (C) 50J (D) 100J
2. **The work done will be zero when angle between the force and distance is:** **(GRW. GII)**
   (A) 90° (B) 45° (C) 60° (D) 180°
3. **The work will be maximum when angle between force and displacement is:** **(RWP. GII)**
   (A) 45° (B) 0° (C) 60° (D) 90°
4. **What is the unit of work?** **(BWP. GI)**
   (A) J (B) N (C) Ns (D) m
5. **One joule is equal to:** **(SWL. GI)**
   (A) $\frac{1N}{1m}$ (B) 1N × 1m (C) $\frac{1m}{1N}$ (D) $\frac{1N^2}{1m^2}$
6. **The kinetic energy of a body of mass 2kg is 25J. Its speed will be:** **(LHR. GI, SWL. GI, BWP. GI)**
   (A) $5ms^{-1}$ (B) $12.5ms^{-1}$ (C) $25ms^{-1}$ (D) $50ms^{-1}$

Answers

1.	100J	2.	90°	3.	0°	4.	J
5.	1N × 1m	6.	$5ms^{-1}$				

☆ **Give short answer to the following questions.**

1. **What is the unit of work? Define it.** **(LHR. GI, SWL. GI, GRW. GII, SGD. GII)**

Ans. SI unit of work: SI unit of work is joule (J).

Joule: The amount of work is one joule when a force of one newton displaces a body through one metre in the direction of force.

Thus, 1J = 1N × 1m

2. How can you find the Efficiency of a System? (MLN. GI, SGD. GI)

Ans. Efficiency of a system can be found out by following formula.

$$\text{Efficiency} = \frac{\text{required form of output}}{\text{total input energy}}$$

$$\%\ \text{Efficiency} = \frac{\text{required form of output}}{\text{total input energy}} \times 100$$

3. Define work. Also give its SI unit. (DGK. GII, LHR. GII, FBD. GII, MLN. GII)

Ans. Work: Work is said to be done when a force acting on a body displaces it in the direction of the force.

Work = Force × distance

SI unit of work: SI unit of work is joule (J)

4. A man has pulled a cart through 35m applying a force of 300N. Find the work done by the man. (RWP. GII)

Data: Distance = S = 35 m

Force = F = 300N

Required: Work done = ?

Formula: $W = F \times S$

Work = Force × distance

Sol: By putting the values in the formula amount of work can be found out.

$W = F \times S$

$W = 35 \times 300$

$\boxed{W = 10500\,J}$

Ans: The required work done by the man is 10500J.

5. Define energy and write names of its different types. (MLN. GI, BWP. GII)

Ans. Energy: A body possesses energy if it is capable to do work.

Types of energy: Energy exists in various types which are given below:

1. Mechanical energy
2. Heat energy
3. Light energy
4. Sound energy
5. Electrical energy
6. Chemical energy
7. Nuclear energy

6. Define kinetic energy also write its equation.

(LHR. GI & GII, SWL. GI & GII, SGD. GII, FBD. GII, MLN. GI & GII, RWP. GII)

Ans. Kinetic Energy: The energy possessed by a body due to its motion is called its kinetic energy.

Equation: $K.E = \frac{1}{2}mv^2$

7. A stone of mass 500 g strikes the ground with velocity of 15ms^{-1}. How much is kinetic energy of stone at the time it strikes the ground. (GRW. GI)

Sol. Mass of stone = m = 500g = 0.5kg

Velocety = v = 15ms^{-1}

K.E = ?

We know that

$$K.E = \frac{1}{2}mv^2$$

$$= \frac{1}{2} \times 0.5 \times (15)^2$$

$$K.E = \frac{1}{2} \times 0.5 \times 225 = 56.25\ J$$

8. Why geothermal wells are made? (GRW. GII)

Ans. Geothermal well can be built by drilling deep near hot rocks at places, where magma is not very deep.

9. The kinetic energy of a body of mass 2kg is 25 J. Find its speed. (GRW. GII)

Sol. Mass = m = 2kg

K.E. = K.E. = 25 J

Speed = V = ?

We know that

$$K.E = \frac{1}{2}mv^2$$

$$25 = \frac{1}{2}(2)v^2$$

$$v^2 = 25$$

$$v = 5ms^{-1}$$ **Ans.**

10. A car weighing 12kN has speed of 20ms^{-1}. Find its Kinetic energy. (SGD. GI)

Sol: Weight = w = 12 kN

Speed = v = 20 ms^{-1}

Required: Kinetic energy = K.E = ?

Formula: $K.E = \frac{1}{2}mv^2$

Solution: Value of K.E can be found out by using above formula

Weight = 12 kN

As we know;

$$w = mg$$

$$\frac{w}{g} = m$$

$$\frac{12k}{10} = m$$

$$m = 1.2\ kg$$

$$K.E = \frac{1}{2}mv^2$$

$$K.E = \frac{1}{2}(1.2)(20)^2$$

$$K.E = \frac{1}{2}(1.2)(400)$$

$$K.E = \frac{1}{2}(480)$$

$$\boxed{K.E = 240\ J}$$

Answer: The required K.E of the car is 240 kJ.

11. A body of mass 0.5kg strikes the ground with the velocity of 20ms⁻¹. Find its Kinetic energy. **(RWP. GI)**

Sol. Mass = m = 0.5kg
Velocety = v = 20ms⁻¹
K.E = ?

We know that

$$K.E = \frac{1}{2}mv^2$$

$$= \frac{1}{2}(0.5)(20)^2$$

$$= \frac{1}{2} \times 0.5 \times 400 = 100\ J$$

Thus, the K.E. of the stone is 100 J as it striks the ground.

6.4+6.5	Potential Energy + Forms of Energy
6.6	Interconversion of Energy

☆ **Tick the correct answer.**

1. Energy stored in a dam's water is: **(GRW. GI, SGD. GII, FBD. GI, GRW. GI, DGK. GI)**
(A) potential energy (B) kinetic energy
(C) thermal energy (D) electrical energy

2. The energy stored in coal is: **(SGD. GI, RWP. GI, FBD. GII, SWL. GII, BWP. GII)**
(A) Neuclear energy (B) Heat energy
(C) Chemical energy (D) Electrical energy

3. The major source of heat energy is: (SGD. GI, RWP. GI)

(A) The moon (B) Nuclear fuels (C) The earth (D) The sun

Answers

1. potential energy 2. Chemical energy 3. The sun

☆ **Give short answer to the following questions.**

1. Define potential energy and write is formula. (GRW. GI, BWP. GII, RWP. GII)

Ans. Potential energy: The ability of a body to do work due to its position is known as its potential energy.

Formula: P.E = mgh

2. A body of 50kg is raised to a height of 3m. Find its potential energy. (FBD. GII)

Sol. m = 50 kg

h = 3m

g = $10\ ms^{-2}$

We know that

P.E. = mgh

∴ P.E. = 50 × 10 × 3 = 1500 J

3. Differentiate between sound energy and mechanical energy. (LHR. GII)

Ans. Sound Energy: Sound is a form of energy.

Sound is produced when a body vibrates.

Following instruments produce sound.

(i) Vibrating diaphragm of a drum.

(ii) Vibrating strings of a sitar.

(iii) Vibrating air column of wind instruments such as flute pipe etc.

(iv) When a door is knocked, a sound is produced.

Mechanical Energy: The energy possessed by a body both due to its motion or position is called mechanical energy.

Examples: Water running down a stream, wind, a moving car, a lifted hammer, a stretched bow, a catapult or a compressed spring etc. possess mechanical energy.

4. Define Work and give its equation. (MLN. GII, SGD. GII, DGK. GII)

Ans. Work: Work is said to be done when a force acting on a body displaces it in the direction of the force.

Work = Force × Distance

5. Write the name of major sources of energy. (FBD. GI)

Ans. Major sources of energy: There are basically two major sources of energy.

1. Fossil Fuels 2. Nuclear Fuels

6. How Chemical Energy is obtained? (SGD. GII. SWL. GII. BWP. GII)

Ans. Chemical energy is present in food, fuels and in other substances. The energy is released from these substances during chemical reactions.

7. How mechanical energy change into heat energy? (LHR. GII. MLN. GI)

Ans. Energy cannot be destroyed however it can be converted from one form to another form. But total energy of the system at any time remains constant.

By rubbing hands quickly, these will be warmed. Its mean in rubbing hands muscular energy is used and as a result heat is produced.

In this process of rubbing hands, mechanical energy is converted into heat energy.

8. Differentiate between mechanical and chemical energy. (SGD. GI)

Ans. Mechanical energy: The energy possessed by a body both due to its motion or position is called mechanical energy.

Examples: Water running down a stream, wind, a moving car, a lifted hammer, a stretched bow, a catapult or a compressed spring etc. possess mechanical energy.

Chemical Energy: Chemical energy is present in food, fuels and in other substances. The energy is released from these substances during chemical reactions.

9. What is Bio mass and how energy is produced from it?(RWP. GI. GRW. GII. DGK. GI)

Ans. Biomas: Biomass is plant or animal wastes that can be burnt as fuel.

When animal dung, dead plants and dead animals decompose, they give off a mixture of methate and carbon dioxide which is used to generate electricity.

10. Write down the names of kinds of Mechanical Energy.

Ans. Mechanical energy has two following types. (RWP. GI & GII. DGK. GI & GII)

1. Kinetic energy
2. Potential energy

11. Describe the difference between electrical energy and light energy. (DGK. GI)

Ans. Electrical energy:

☆ Electricity is one of the widely used form of energy.

☆ Electrical energy can get form batteries and electric generators. Most of the electric generators are run by hydro power, thermal or nuclear power.

Light energy:

☆ Light is an important form of energy.

☆ Sun is the great source of light energy.

☆ Light energy can be obtained from candles, electric bulbs, fluorescent tubes and also by burning fuel.

12. What are environmental problems and why are they created? (DGK. GII)

Ans. Environmental problems such as pollution that consist of noise, air pollution and water pollution may arise by using different sources of energy such as fossil fuels and nuclear energy.

13. What is the use of solar cells? (DGK. GII)

Ans. Uses of solar cells:

⇒ Solar cells can provide power to telephone booths, light houses and scientific research centres.

⇒ Solar cells are also used to power satellites.

14. Define sound energy. (LHR. GI)

Ans. Sound energy: Sound is a form of energy. Sound is produced when a body vibrates.

15. Define electrical energy and sound energy. (GRW. GII)

Ans. Electrical energy: Electricity is one of the widly used form of energy. Electrical energy can be supplied through wires, easily to any desired place.

Sound energy: Sound is a form of energy. Sound is produced when a body vibrates.

16. How energy is produced by nuclear fuels? Explain. (FBD. GI, DGK. GI)

Ans. The process taking place in nuclear reactors is known as nuclear fission. During fission reaction, the heavy nucleus of an atom splits up into smaller parts releasing a large amount of energy. Nuclear power plants give out a lot of nuclear radiations and vast amount of heat.

17. Write the names of any two non renewable and renewable sources of energy. (SWL. GI)

Ans. Non-renewable source of energy: 1. Fossil fuels 2. Nuclear fuels

Renewable sources of energy: 1. Solar energy 2. Water power

18. Which form of energy is most preferred and why? (SWL. GI)

Ans. Solar energy is most preferred energy because Sunlight does not pollute the environment in any way.

19. What is meant by non-renewable source? Write an example. (DGK. GII)

Ans. Non-renewable source: The fossile fuels took millions of years for their formation, so, they are known as non-renewable resources.

For example: Oil, gas, coal.

20. Write the names of the parts of Solar Heating System. (SWL. GII, BWP. GI)

Ans. A heating system consists of

☆ A collecter ☆ A storage device ☆ A distribution system

21. Write two Renewable Energy Sources. Explain one of them shortly. (BWP. GI)

Ans. 1. Energy from water

2. Energy from sun

Energy from water: Energy from water power is very cheap. Water power is becoming more popular. For water power dams are being constructed at suitable location in different parts of the world.

6.7	Major Sources of Energy
6.8+6.9	Efficiency+Power

☆ Tick the correct answer.

1. Which one of the following device converts light energy into electrical energy: (LHR. GII, MLN. GII, SGD. GI)

(A) Electric bulb (B) Electric generator (C) Photo cell (D) Electric cell

2. In Einstein's mass-energy equation c is the: (LHR. G II, MLN. GI & GII)

(A) Speed of sound (B) Speed of light

3. The efficiency percentage of an electric lamp is: (RWP. GI)

(A) 5% (B) 10% (C) 15% (D) 20%

(C) Speed of earth (D) Speed of electron

4. Rate of doing work is called: (FBD. GI, RWP. GI, SGD. GII, DGK. GI & GII)

(A) Energy (B) Torque (C) Power (D) Momentum

5. One Horse Power is equal to: (MLN. GI)

(A) 740W (B) 746W (C) 750W (D) 756

6. One megawatt is equal to: (DGK. GII)

(A) 10^3W (B) 10^5W (C) 10^4kW (D) 10^3kW

7. One Mega Watt is equal to: (BWP. GII)

(A) 10^2W (B) 10^4W (C) 10^6W (D) 10^8W

Answers

1.	Photo cell	2.	Speed of light	3.	5%	4.	Power
5.	746W	6.	10^4kW	7.	10^6W		

☆ Give short answer to the following questions.

1. Write down the equation of Einstein and value of c.

(LHR. GII, FBD. GI & GII, SWL. GII, GRW. GI, BWP. GII)

Ans. The relation between mass (m) and energy (E) is given by Einstein mass energy equation:

$$E = mc^2$$

Here c is the speed of light.

Its value is 3×10^8 ms^{-1}

2. How can every citizen be helpful in controlling air pollution? (GRW. GI)

Ans. Every citizen can be helpful in controlling air pollution by sharing rides and using

public transport, due to this less fuel and energy is used and less pollutants are released in the environment.

3. Write the uses of wind energy. (GRW. GII, MLN. GII, BWP. GII, DGK. GII)

Ans. Uses of Wind energy:

1. Wind energy has powered sailing ships across the oceans.
2. Wind energy has been used by windmills to grind grain and pump water.
3. More recently, wind power is used to turn wind turbines.

4. Write two disadvantages of thermal pollution. (GRW. GII)

Ans.
- ☆ Thermal pollution upsets the balance of life.
- ☆ Thermal pollution endangers the survival of many species.

5. Define nuclear energy. (FBD. GI, RWP. GI & GII, SGD. GI)

Ans. Nuclear energy: Nuclear energy is the energy released in the form of nuclear radiations in addition to heat and light during nuclear fission and fusion reactions.

6. What is meant by solar cells? (FBD. GI)

Ans. Solar Cells: Solar energy can also be converted directly into electricity by solar cells.

7. By defining magma, describe geothermal energy. (FBD. GII)

Ans. There is hot molten part, deep in the Earth called magma. Water reaching close to the magma changes to steam due to the high temperature of magma. This energy is called geothermal energy.

8. How can we produce electricity by using of animal dung? (FBD. GII)

Ans. When animal dung, dead plants and dead animals decompose, they give off a mixture of methane and carbon dioxide. Electricity can be generated by burning methane.

9. Define Mechanical Energy. (MLN. GII, LHR. GII, FBD. GII, SGD. GI)

Ans. Mechanical Energy: The energy possessed by a body both due to its motion or position is called mechanical energy.

Examples: Water running down a stream, wind, a moving car, a lifted hammer, a stretched bow, a catapult or a compressed spring etc. possess mechanical energy.

10. Why fossil Fuels are known as nonrenewable sources? (MLN. GII, SGD. GI)

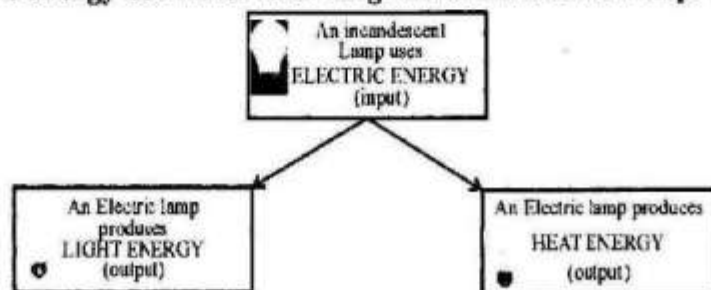
Ans. The fossil fuels take millions of years for their formation. So these are known as non-renewable resources.

11. Construct the energy converter flow diagram of an electric lamp. (GRW. GI, 2015)

Ans.

An incandescent Lamp uses ELECTRIC ENERGY (input)

An Electric lamp produces LIGHT ENERGY (output)

An Electric lamp produces HEAT ENERGY (output)

12. How energy is converted from one form to another? Explain. (SWL. GII, RWP. GII, DGK. GI, BWP. GI)

Ans. Energy cannot be destroyed however it can be converted from one form to another form. But total energy of the system at any time remains constant.

By rubbing hands quickly, these will be warmed. Its mean in rubbing hands muscular energy is used and as a result heat is produced.

In this process of rubbing hands, mechanical energy is converted into heat energy.

13. Name the Four devices that convert electrical energy into mechanical energy. (SGD. GII)

Ans. ⇒ Juicer ⇒ Electric motor
⇒ Electric grinder ⇒ Electric spinner

14. Write two disadvantages of Fossil Fuels. (BWP GI)

Ans. ⇒ Once the supply of fossil fuels is exhausted, the world would face serious energy crisis.

⇒ Fossil fuels would not be able to meet our future energy demands.

⇒ Exhausted supply of fossil fuels would cause serious social and economical problems for countries like us.

15. What is meant by efficiency of a system? (FBD. GI, SWL. GI, BWP. GII, BWP. GI)

Ans. Efficiency of a system: Efficiency of a system is the ratio of required form of enregy obtained from a system as output to the total energy given to it as input.

16. Name two devices that convert Electrical Energy into Mechanical Energy. (MLN. GI)

Ans. 1. Washing machine 2. Juicer 3. Electric motor
4. Electric grinder 5. Electric spinner

17. A cyclist does 12 J of useful work while pedalling, his bike from energy 100 joules of food energy which he takes. What is his efficiency? (DGK. GI)

Sol. Useful work done by the cyclist = 12 J

Energy used by the cyclist = 100J

$$\text{Efficiency} = \frac{12\text{J}}{100\text{J}}$$

$$= 0.12$$

$$\text{or \% efficiency} = 0.12\times 100$$

$$= 12\ \%$$

The efficiency of the cyclist is 12 %.

18. Define Efficiency and also write its equation. (MLN. GI & II, GRW. GII)

Ans. Efficiency: Efficiency of a system is the ratio of required form of energy obtained from a system as output to the total energy given to it as input.

Formula of efficiency: Efficiency can be obtained by following formula.

$$\text{Efficiency} = \frac{\text{required form of output}}{\text{Total input energy}}$$

19. Efficiency is a ratio between two quantities write their names. (DGK. GII)

Ans. Efficiency of a system is the ratio of required form of energy obtained from a system as output to the total energy given to it as input.

20. Define power and write its formula.
(LHR. GII, SWL. GI & GII, FBD. GI & GII, RWP. GI & GII, SGD. GI, DGK. GI, MLN. GI, GRW. GI & GII)

Ans. Power: Power is defined as the rate of doing work.

Formula: $\text{Power} = \dfrac{\text{work done}}{\text{time taken}}$

$$P = \frac{W}{t}$$

21. Define watt. (GRW. GI, BWP. GI)

Ans. Watt: The SI unit of power is watt.

The power of a body is one watt if it does work at the rate of 1 joule per second ($1 Js^{-1}$).

22. Define watt and write how much watt is equal to one horsepower?
(SWL. GII, SGD. GII, FBD. GI)

Ans. Watt: The power of a body is one watt if it does work at the rate of 1 joule per second ($1 Js^{-1}$)

1 horse power = 1 hp = 746 watt

23. If a body does 11200 Joule work in 10 seconds, find the power. (RWP. GI)

Ans. work = w = 11200 J
time = t = 10 sec
power = p = ?

we know that

$$P = \frac{w}{t} = \frac{11200}{10}$$

$$P = 1120 \text{ watt}$$

24. A machine does 20 joule work in 4 seconds. Find its Power. (BWP. GI)

Ans. Work = W = 20 J
time = t = 4 sec
Power = P = ?

we know that

$$P = \frac{W}{t}$$

$$P = \frac{20}{4} = 5 \text{ watt}$$

PROPERTIES OF MATTER

STUDENTS LEARNING OUTCOMES

After studying this unit, the students will be able to:

- state kinetic molecular model of matter (solid, liquid and gas forms).
- describe briefly the fourth state of matter i.e. Plasma.
- define the term density.
- compare the densities of a few solids, liquids and gases.
- define the term pressure (as a force acting normally on unit area).
- explain how pressure varies with force and area in the context of everyday examples.
- explain that the atmosphere exerts a pressure.
- decribe how the height of a liquid column may be used to measure the atmospheric pressure.
- describe that atmospheric pressure decreases with the increase in height above the Earth's surface.
- explain that changes in atmospheric pressure in a region may indicate a change in the weather.
- state Pascal's law.
- apply and demonstrate the use with examples of Pascal's law.
- state relation for pressure beneath a liquid surface to depth and to density i.e., ($P = \rho gh$) and solve problems using this equation.
- state Archimedes principle.
- determine the density of an object using Archimedes principle.
- state the upthrust exerted by a liquid on a body.
- state principle of floatation.
- explain that a force may produce a change in size and shape of a body.
- define the terms stress, strain and Young's modulus.
- state Hooke's law and explain elastic limit.

Conceptual Linkage:	
This unit is built on	
Matter and its States	–Science–V
This unit leads to:	
Fluid Dynamics	–Physics–XI
Physics of Solids	–Physics–XII

INVESTIGATION SKILLS:

- measure the atmospheric pressure by Fortin's barometer.
- measure the pressure of motor bike/car tyre and state the basic principle of the

instrument and its value in SI units.

- Determine the density of irregular shaped objects.

SCIENCE, TECHNOLOGY AND SOCIETY CONNECTION:

Major Concepts:

- explain that to fix a thumb pin, pressure exerted on the top increases thousands time on the pin point.
- explain the use of Hydrometer to measure the density of a car battery acid.
- explain that ships and submarines float on sea surface when the buoyant force acting on them is greater than their total weight.
- state that Hydraulic Press, Hydraulic car lift and Hydraulic brakes operate on the principle that the fluid pressure is transmitted equally in all directions.
- explain that the action of sucking through a straw, dropper, syringe and vacuum cleaner is due to atmospheric pressure.

Introduction: Matter exists in three states, solid, liquid and gas. There are many properties associated with matter. For example, matter has weight and occupies space. There are some other properties which are associated with one state of matter but not with other. For example, solids have shape of their own while liquids and gases do not. Liquids on the other hand have definite volume while gaes do not have. Various materials differ in their hardnes, density, solubility, flow, elasticity, conductivity and many other qualities. Kinetic molecular model helps in understanding the properties of matter in a simplified way.

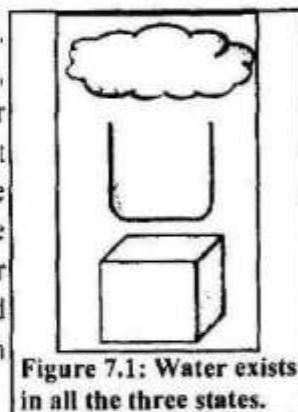



Figure 7.1: Water exists in all the three states.

7.1 Kinetic Molecular Model of Matter

Q1. What are the important features of kinetic molecular model? How three states of matter can be explained by kinetic molecular model.

Ans. Kinetic molecular model is used to explain the three states of matter-solid, liquid and gas. Kinetic molecular model of the three states of matter can be shown in the given figure.

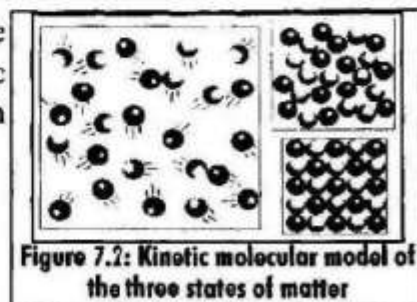



Figure 7.2: Kinetic molecular model of the three states of matter

Kinetic theory has some important features.

- Matter is made up of particles called molecules.
- The molecules remain in continuous motion.
- Molecules attract each other.

Explanation of three states of matter:

The kinetic molecular model is used to explain the three states of matter.

(i) Solids (ii) Liquid (iii) Gas

(i) Solids: Solids have following characteristics according to kinetic molecular model.

Figure 7.3: Molecules are closely packed in solids

(a) Fixed shape and volume: Solids have fixed shape and volume.

(b) Strong forces of attraction: Molecules of solids are held close together by strong forces of attraction as shown in the given figure.

(c) Vibratory motion: The molecules of solids vibrate about their fixed mean position but do not move from place to place.

(d) Examples: Stone, metal, spoon and pencil are some examples of solids.

(ii) Liquids: Liquids have following characteristics according to kinetic molecular model.

Figure 7.4: Molecules are loosely packed in liquids

(a) Fixed volume but not fixed shape: The volume of a certain amount of liquid remains the same but because of flow property it attains the shape of the container.

(b) Weak attractive forces:

The distances between the molecules of a liquid are more than in solids. Thus attractive forces between them are weaker as shown in the given figure.

(c) Vibratory motion: Like solids, the molecules of a liquid also vibrate about their mean positions but are not rigidly held with each other.

(d) Property of flow: Due to the weaker attractive forces between the molecules of liquids, they can slide over each other. Thus the liquids have property to flow.

Examples: Water, oil, honey and petrol are some examples of liquids.

(iii) Gases: Gases have following characteristics according to the kinetic molecular model.

Figure 7.5: Molecules are much farther apart in gases.

(a) No fixed shape or volume: Gases have no fixed shape or volume. They can be filled in any container of any shape.

(b) Weakest force of attraction: In gases, the molecules are much farther apart than solids or liquids as shown in the figure.

(c) Gases are less denser: Gases are much less denser than solids and liquids. They can be squeezed into smaller volumes.

(d) Random motion: Molecules of gases have random motion and move with very high velocities.

(e) Pressure of gases: The molecules of gases are constantly striking the walls of a container as they move with very high velocities. Thus, a gas exerts pressure on the walls of the container.

Q2. What is plasma? How it can be explained as a fourth state of matter on the basis of kinetic molecular model of matter?

Ans. Plasma: At very high temperature, the matter assumes the state of ions and electrons. This state is called plasma.

Formation of plasma: The kinetic energy of gas molecules goes on increasing if a gas is heated continuously. This causes the gas molecules to move faster and faster. The collisions between atoms and molecules of the gas become so strong that they tear off the atoms. Atoms lose their electrons and become positive ions. This ionic state of matter is called **plasma.**

Plasma in discharge tube: Plasma is also formed in gas discharge tubes when electric current passes through these tubes.

Fourth state of matter: Plasma is called the fourth state of matter in which a gas occurs in its ionic state.

Figure 7.6: A plasma bulb

Separation of positive ions and electrons in plasma:

Positive ions and electrons get separated in the presence of electric or magnetic fields.

Existence of plasma in Universe:

Most of the matter that fills the universe is in plasma state.

⇒ In stars such as our Sun, gases exist in their ionic state.

⇒ Plasma also exists in neon and fluorescent tubes.

Importance of Plasma: Plasma is highly conducting state of matter. It allows electric current to pass through it.

7.2 Density

Q3. What do you know about density? Write its formula and unit. Give one example to explain density.

Ans. Density: The density of a substance is the ratio of its mass to that of its volume.

OR

Density of a substance is defined as its mass per unit volume.

Formula or mathematical form:

$$\text{Density} = \frac{\text{mass of a substance}}{\text{volume of that substance}}$$

$$\text{Density} = \frac{m}{V} \longrightarrow \boxed{1}$$

Density can be calculated if values of mass and volume are known.

Unit: SI unit of density is kilogramme per cubic metre (kgm^{-3}).

Example:

The mass of 5 litre of water is 5kg.

DO YOU KNOW?	
1 meter cube $1m^3$	= 1000 litre
1 litre	$= 10^{-3}m^3$
$1cm^3$	$= 10^{-6}m^3$
$1000\ kgm^{-3}$	$= 1\ gcm^{-3}$

Its density can be calculated by putting the values in eq (1). Thus;

1 litre = 10^{-3} m³

5 litre = 5×10^{-3} m³

$$\text{Density of water} = \frac{5\text{kg}}{5\times10^{-3}\text{m}^3}$$

Density of water = 1000 kgm^{-3}

The density of water is 1000 kgm^{-3}.

Substance	Density in kgm^{-3}
Air	1.3
Foam	89
Petrol	800
Cooking Oil	920
Ice	920
Water	1000
Glass	2500
Aluminum	2700
Iron	7900
Copper	8900
Lead	11200
Mercury	13600
Gold	19300
Platinum	21500

Density equations:

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

$$\text{Mass} = \text{Density} \times \text{Volume}$$

$$\text{Volume} = \frac{\text{Mass}}{\text{Density}}$$

Density can be understood by following case:

If we take equal volumes of iron and wood, then we can easily declare that iron is heavier and denser than wood.

The reason is that mass of iron is much greater than wood of the same volume. Generally for comparing the density of various substances, we compare the mass of equal volume of the materials.

Example 7.1 ***The mass of 200 cm³ of stone is 500 g. Find its density.***

Solution: m = 500g

V = 200 cm³

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

$$\text{Density} = \frac{500\text{ g}}{200\text{ cm}^3} = 2.5\text{ g cm}^{-3}$$

Thus the density of stone is 2.5 g cm^{-3}

7.3 Pressure

Q4. How will you define and explain pressure? Write its formula and unit.

Ans. Pressure:

The force acting normally per unit area on the surface of a body is called pressure.

Formula or mathematical form:

Mathematically, pressure can be written and calculated as,

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

$$P = \frac{F}{A}$$

Figure 7.7: Smaller is the area, larger will be the pressure

Scalar quantity: Pressure is a scalar quantity, because it only needs magnitude for its complete description.

Unit of Presure: In SI units, the unit of pressure is Nm^{-2} also called pascal (Pa).

Thus $1Nm^{-2} = 1$ Pa

Relation of pressure with area: Pressure and area are inversely proportional to each other.

Smaller is the area, larger will be the pressure as shown in given figure.

Figure 7.8: A drawing pin with a sharp tip enters easily when pressed on a wooden board.

If the effective area of the force is reduced then the effectiveness of a small force is increased.

Example: A drawing pin can be pushed into a wooden board by pressing it by our thumb. It is because the force that is applied on the drawing pin is confined just at a very small area under its sharp tip as shown in given figure.

A drawing pin with a blunt tip would be very difficult to push into the board due to the large area of its tip.

Pressure can also be defined as:

The quantity that depends upon the force and increases with decrease in the area on which force is acting is called pressure.

7.4 Atmospheric pressure

Q5. What is atmosphere? How atmospheric pressure can be explained? Write a simple experiment.

Ans. Atmosphere and atmospheric presssure:

The Earth is surrounded by a cover of air called atmosphere. It extends to a few hundred kilometers above sea level. Just as certain sea creatures live at the bottom of ocean, the humans live at the bottom of huge ocean of air. The pressure of atmosphere is called atmospheric pressure.

Air:

Air is a mixture of gases.

Direction of atmospheric pressure:

Atmospheric pressure acts in all directions.

Relation of height with atmospheric pressure:

The atmospheric pressure decreases continuously as we go up. Thus knowing the atmospheric pressure of a place, its altitude can be determined.

DENSITY AND THE ATMOSPHERE

Earth's atmosphere extends upward about a few hundred kilometres with continuously decreasing density. Nearly half of its mass is between sea level and 10 km. Up to 30 km from sea level contains about 99% of the mass of the atmosphere. The air becomes thinner and thinner as we go up.

Example # 1.

The formation of spherical shape, soap bubbles as shown in given figure is an example which represents that atmospheric
pressure acts on it equally in all directions.

A soap bubble expands till the pressure of air in it is equal to the atmospheric pressure.

Figure 7.9: The air pressure inside the bubble is equal to the atmospheric pressure

Example # 2.

A balloon expands as it is filled with air. Air exerts a pressure inside the balloon which expands till it is equal to the atmospheric pressure as shown in figure (7.10).

Figure 7.10: Air pressure inside the balloon is equal to the atmospheric pressure

Explanation by Experiment: Atmospheric pressure can easily be understood by a simple experiment. The steps of experiment are as following.

1. Take an empty tin can with a lid.
2. Open its cap and put some water in it.
3. Place it over flame.
4. Wait till water begins to boil and the steam expels the air out of the can.
5. Remove it from the flame.
6. Close the can firmly by its cap.
7. Place the can under tap water. The can will squeeze due to atmospheric pressure.

Figure 7.11: Crushing can experiment

Conclusion: The experiment shows that atmosphere exerts pressure in all direction:

Reason of collapsing the can:

When the can is cooled by tap water, the steam in it condenses.

As the steam changes into water, it leaves an empty space behind it. This lowers the pressure inside the can as compared to the atmospheric pressure outside the can. This will cause the can to collapse from all directions.

Collapsing of plastic bottle: Atmosphere exerts pressure in all directions can be demonstrated by collapsing of an empty plastic bottle when air is sucked out of it.

Q6. How atmospheric pressure can be measured?

Ans. Barometers: The instruments that measure atmospheric pressure are called barometers. One of the simple barometers is a mercury barometer as shown in the figure.

Construction of mercury barometer: Mercury barometer consists of a glass tube 1m long closed at one end.

After filling the glass tube it with mercury, it is inverted in a mercury trough.

Mercury in the tube descends and stops at a certain height.

Column of mercury: The column of mercury held in the tube exerts pressure at its base.

Height and pressure of mercury column:

The height of mercury column above the mercury in the trough is found to be about 76cm at the sea level.

Pressure exerted by 76cm of mercury column is nearly 101,300 Nm^{-2} equal to atmospheric pressure.

Relation of atmospheric pressure with height of mercury column:

It is common to express atmospheric pressure in terms of the height of mercury column.

Figure 7.12: A mercury barometer

As the atmospheric pressure at a place does not remain contant, hence, the height of mercury column also varies with atmospheric pressure.

Density of mercury: Mercury is 13.6 times more denser than water.

Height of water barometer: Atmospheric pressure can hold vertical column of water about 13.6 times the height of mercury column at a place.

Thus, at sea level, vertical height of water column would be $0.76m \times 13.6 = 10.34$ m. Thus, a glass tube more than 10m long is required to make a water barometer.

Q7. How will you explain variation in atmospheric pressure?

Ans. Height and atmospheric pressure:

The atmospheric pressure decreases as we go up.

Atmospheric pressure on mountains:

The atmospheric pressure on mountains is lower than at sea level.

Atmospheric pressure at a 30km height:

At a height of about 30km, the atmospheric pressure becomes only 7mm of mercury which is approximately 1000 Pa.

Atmospheric pressure on altitude where no air is present: Atmospheric pressure become zero at an altitude where there is no air.

Determination of altitude by atmospheric pressure:

By atmospheric pressure of a place, its altitude can also be determined.

Weather and atmospheric pressure:

Atmospheric pressure may also indicate a change in the weather.

Atmospheric pressure on a hot day: On a hot day, air above the Earth becomes hot and expands. This causes a fall of atmospheric pressure in that region.

DO YOU KNOW?

The fan in a vacuum cleaner lowers air pressure in its bucket. The atmospheric air rushes into it carrying dust and dirt with it through its intake port. The dust and dirt particles are blocked by the filter while air escapes out.

Atmospheric pressure in a cold night: During cold chilly nights, air above the Earth cools down. This causes an increase in atmospheric pressure.

Indication of weather conditions by atmospheric pressure:

Changes in atmospheric pressure at a certain place indicate the expected changes in the weather conditions of that place.

Effects of minor and gradual fall in atmospheric pressure:

A gradual and average drop in atmospheric pressure means a low pressure in a neighbouring locality.

(a) Windy and showery condition: Minor but rapid fall in atmospheric pressure indicates a windy and showery condition in the nearby region.

(b) Breeze and rain: A decrease in atmospheric pressure is accompanied by breeze and rain.

Effect of sudden fall in atmospheric pressure: A sudden fall in atmospheric pressure often followed by a storm, rain and typhoon to occur in few hours time.

Do YOU KNOW?

When air is sucked through straw with its other end dipped in a liquid, the air pressure in the straw decreases. This causes the atmospheric pressure to push the liquid up the straw.

Effects of increasing atmospheric pressure: An increasing atmospheric pressure with a decline later on predicts an intense weather conditions.

(a) Long spell of pleasant weather: A gradual large increase in the atmospheric pressure indicates a long spell of pleasant weather.

(b) Poor weather: A rapid increase in atmospheric pressure means that it will soon be followed by a decrease in the atmospheric pressure indicating poor weather ahead.

7.5 Pressure In Liquids

Q8. How pressure in liquids can be defined and explained? Also derive the formula which is used to find out the pressure of liquid.

Ans. Definition: The force acting on unit area is called pressure.

Pressure of liquid: Liquid exerts pressure. The pressure of a liquid acts in all directions.

Pressure sensor: Pressure sensor is a device which is used to measure pressure.

Pressure varies with depth: With the help of a pressure sensor, it can be observed that the pressure of the liquid varies with depth.

Explanation: Consider a surface of area (A) in a liquid at a depth (h) as shown by shaded region in given figure.

- ☆ The length of the cylinder of liquid over this surface will be h.
- ☆ The force acting on this surface will be the weight w of the liquid above this surface.
- ☆ ρ is the density of the liquid.
- ☆ m is mass of liquid above the surface.

As we know:

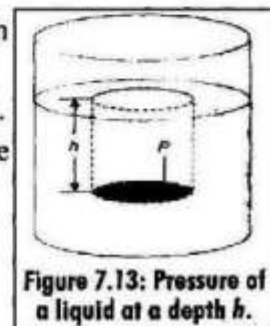



Figure 7.13: Pressure of a liquid at a depth *h*.

mass = volume × density

so,

Mass of the liquid cylinder (m) = volume × density ⟶ ①

$\therefore$ volume = A × h

$\therefore$ density = ρ

By putting these value in equation ①

$m = (A \times h) \times \rho$

Force acting on area A = F = w = mg

Force acting on area a = F = mg ⟶ ②

By putting the value of mass in equation ②

$F = (A \times h \times \rho)g$

$F = A\,h\,\rho g$ ⟶ ③

Pressure can be found as:

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

$$P = \frac{F}{A} \longrightarrow ④$$

By putting the value of force from equation ③ into eq ④ we get;

$$P = \frac{\cancel{A} h\rho g}{\cancel{A}}$$

$P = h\rho g$

So liquid pressure at depth h = $P = h\rho g$ = ⟶ ⑤

Equation (5) gives the pressure at the depth h due to a liquid of density ρ.

It shows that inside a liquid, its pressure increases with depth.

Do YOU KNOW?

The piston of the syringe is pulled out. This lowers the pressure in the cylinder. The liquid from the bottle enters into the piston through the needle.

Q9. How will you define and explain Pascal's law:

Ans. Pascal's law: Pressure applied at any point of a liquid enclosed in a container, is transmitted without loss to all other parts of liquid.

Explanation: An external force applied on the surface of a liquid increases the liquid pressure at the surface of the liquid.

This increase in liquid pressure is transmitted equally in all directions and to the walls of container in which it is filled.

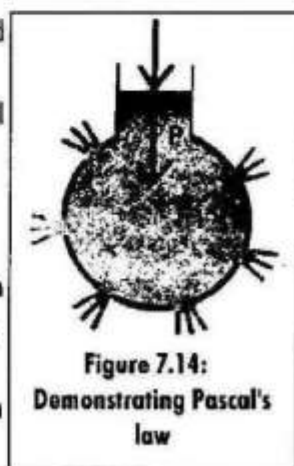
Demonstration of Pascl's law by a simple experiment:

Pascal's law can be demonstrated by a simple experiment.

The apparatus of this demonstration is shown in the given figure. It is a simple glass vessel having holes all over its surface.

(1) Fill this glass vessel with water.

(2) Push the piston. By pushing the force applied on the piston exerts pressure on water.

Figure 7.14: Demonstrating Pascal's law

(3) The applied pressure is transmitted equally throughout the liquid in all directions.

(4) By transmission of the applied pressure the water rushes out of the holes in the vessel with the same pressure.

Importance of pascal's law:

In general, Pascal's law holds good for fluids both for liquids as well as gases.

Q10. What are the applications of Pascal's law. Alo explain the working of hydraulic press.

Ans. Applications of Pascal's law:

Pascal's law finds numerous applications in our daily life.

Automobiles, hydraulic brake system, hydraulic jack, hydraulic press and other hydraulic machines all follows the Pascal's law. Hydraulic excavator is shown in the given figure follows the pascal's law.

Figure 7.15: Hydraulic excavator

Hydraulic press: Hydraulic press is a machine which works on Pascal's law.

Construction of hydraulic press: Hydraulic press consists of two cylinders of different cross-sectional areas as shown in the given figure.

These both cylinders are fitted with pistons of cross-sectional areas a and A.

Working of hydraulic press:

In the hydraulic press the object which has to be compressed place over the piston of large cross-sectional area A, the force F_1 is applied on piston of small cross-sectional area (a.)

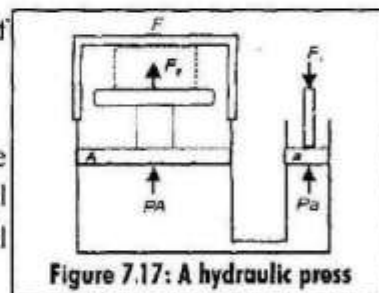



Figure 7.17: A hydraulic press

The pressure P, produced by small piston is transmitted equally to the large piston and a force F_2 acts on A, which is much larger than F_1.

Pressure on piston of small area: Pressure on piston of small area (a) is given by:

$$P = \frac{F_1}{a} \longrightarrow ①$$

Pressure on piston of large area: According to Pascal's law, the pressure on large piston of area A will be the same as on the small piston.

$$P = \frac{F_2}{A} \longrightarrow ②$$

By comparing eq ① and ② we get.

$$\frac{F_2}{A} = \frac{F_1}{a}$$

$$F_2 = \frac{F_1}{a} \times A$$

$$F_2 = \frac{A}{a} \times F_1$$

Since the ratio $\frac{A}{a}$ is greater than 1.

Hence, the force (F_2) that acts on the larger piston is greater than the force F_1 acting on the smaller piston.

Hydraulic systems working in this way are known as force multipliers.

Example 7.2

In a hydraulic press, a force of 100 N is applied on the piston of a pump of cross- sectional area 0.01m². Find the force that compresses a cotton bale placed on larger piston of cross-sectional area 1m².

Solution: Here $F_1 = 100N$

$a = 0.01m^2$

$A = 1\ m^2$

Pressure P on smaller piston $= \frac{F_1}{a}$

$$= \frac{100N}{0.01m^2} = 10000\ Nm^{-2}$$

Applying Pascal's law, we get;

$\therefore$ Force F_2 acting on the bale $= PA$

$= 10000\ Nm^{-2} \times 1m^2 = 10000\ N$

$\therefore$ The hydraulic press will compress the bale with a force of 10000 N.

Q11. What is the principle of braking system in vehicles? Explain.

Ans: The braking systems of cars, buses, etc. also work on Pascal's law.

Hydraulic brakes: The hydraulic brakes system is shown in the given figure, allow equal pressure to be transmitted throughout the liquid.

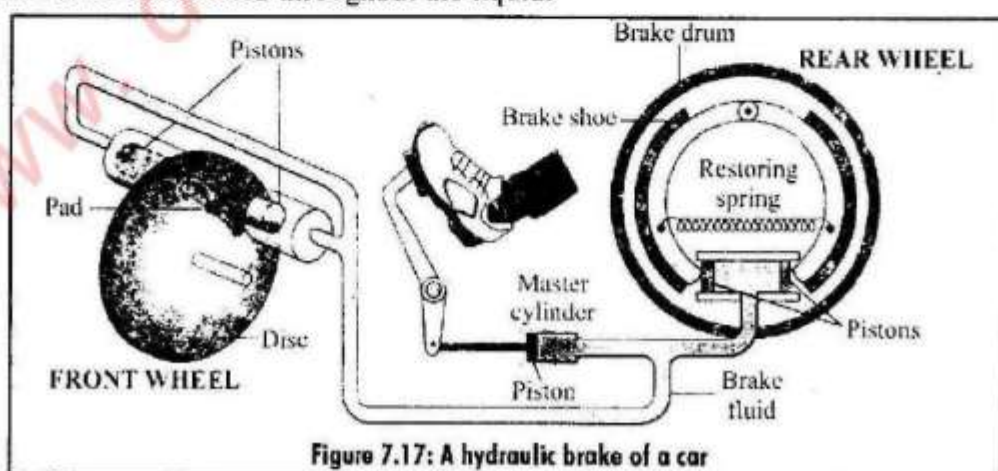



Figure 7.17: A hydraulic brake of a car

Working of braking system in vehicles:

Working of braking system can be easily understood step wise.

Step I: When brake pedal is pushed, it exerts a force on the master cylinder, which increases the liquid pressure in it.

Step II: The liquid pressure is transmitted equally through the liquid in the metal pipes to all the pistons of other cylinders.

Step III: Due to the increase in liquid pressure, the pistons in the cylinders move outward pressing the brake pads with the brake drums.

Step IV: The force of friction between the brake pads and the brake drums stop the wheels.

7.6 Archimede's Principle

Q12. What is Archimedes principle? Write an extensive and detail note.

Ans. Archimedes Principle: When an object is totally or partially immersed in a liquid, an up-thrust acts on it equal to the weight of the liquid it displaces.

Up-thrust force:

There is an upward force which acts on an object kept inside a liquid. It apparently makes the object to lose weight. This upward force is called the up-thrust of the liquid.

Importance of up-thrust force:

(1) An air filled balloon immediately shoots up the surface when released under water. The same would happen if a piece of wood is released under water.

(2) It is our common observation that a mug filled with water feels light under water but feels heavy as soon as it is taken out of water.

In the above two cases a force which is responsible is called upthrust force.

Upthrust force is introduced by the Greek scientist, Archimedes more than two thousands years ago.

Mathematical explanation of Archimedes law: Consider a solid cylinder of cross-sectional area (A) and height (h) immersed in a liquid as shown in the given figure.

Let depth of the top face of cylinder = h_1

depth of the bottom face of cylinder = h_2

So difference in depth of top and bottom faces of cylinder.

$h_2 - h_1 = h$

Let P_1 is the pressure of liquid at depth h_1.

Let P_2 is the pressure of liquid at depth h_2.

ρ is the density of liquid.

$P_1 = \rho g h_1$

$P_2 = \rho g h_2$

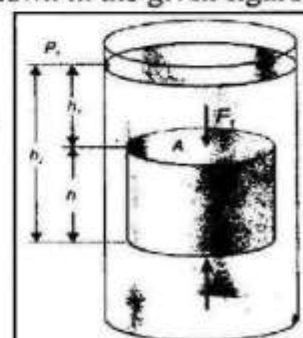



Figure 7.18: Upthrust on a body immersed in a liquid is equal to the weight of the liquid displaced.

Let the force F_1 is exerted at the cylinder top by the liquid due to pressure P_1.

Let the force F_1 is exerted at the cylinder top by the liquid due to pressure P_1.

So $F_1 = P_1 A \longrightarrow$ ①

By putting the value of P_1 in equation ①

$F_1 = \rho g h_1 A$

Let the force F_2 is exerted at the bottom of cylinder by the liquid due to P_2.

$F_2 = P_2 A \longrightarrow$ ②

By putting the value of P_2 in equation ②

$F_2 = \rho g h_2 A$

F_1 and F_2 are acting on the opposite faces of the cylinder. Therefore, the net force F will be $F_2 - F_1$ in the direction of F_2.

Net force of the sytem: Net force F will be $F_2 - F_1$ in the direction of F_2. This net force F on the cylinder is called the upthrust of the liquid.

$F_2 - F_1 = \rho g h_2 A - \rho g h_1 A$

$F_2 - F_1 = \rho g A (h_2 - h_1)$

$\because F_2 - F_1 =$ upthrust of liquid

$h_2 - h_1 = h$

So,

Upthrust of liquid $= \rho g A h \longrightarrow$ ③

As we know $Ah = V$

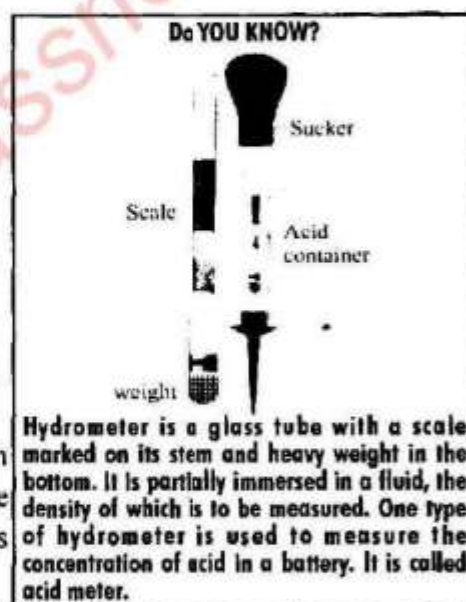
By putting the value of Ah, eq ③ becomes:

Upthrust of liquid $= \rho g V \longrightarrow$ ④

It is clear now that upthrust of liquid depends on density, gravitational acceleration and volume.

Equation ④ shows that an upthrust acts on the body immersed in a liquid and is equal to the weight of liquid displaced, which is Archimedes principle.

Do YOU KNOW?

Hydrometer is a glass tube with a scale marked on its stem and heavy weight in the bottom. It is partially immersed in a fluid, the density of which is to be measured. One type of hydrometer is used to measure the concentration of acid in a battery. It is called acid meter.

Example 7.3 ***A wooden cube of sides 10cm each has been dipped completely in water. Calculate the upthurst of water acting on it.***

Solution: Length of side L $= 10\text{cm} = 0.1\text{m}$

Volume V $= L^3$

$= (0.1\text{m})^3 = 1 \times 10^{-3}\text{m}^3$

Density of water $\rho = 1000 \text{ kg m}^{-3}$

Upthurst of water $= \rho g V$

$= 1000 \text{ kg m}^{-3} \times 10\text{m s}^{-2} \times 1 \times 10^{-3}\text{m}^3$

$= 10\text{N}$

Thus, upthurst of water acting on the wooden cube in 10N.

Q13. How density of an object can be found out by Archimedes principle? Explain.

Ans: Archimedes principle is very helpful to determine the density of an object.

Densities of bodies: The ratio in the weights of a body with an equal volume of liquid is the same as in their densities.

Mathematical form:

Let: Density of the object = D

Density of the liquid = ρ

Weight of the object = w_1

Weight of equal volume of liquid = $w = w_1 - w_2$

w_2 is the weight of the solid in liquid.

According to Archimedes principle, w_2 is less than its actual weight w_1 by an amount w.

Figure 7.19: (a) weighing solid in air (b) weighing solid in water and measuring water displaced by the solid.

Since $\frac{D}{\rho} = \frac{w_1}{w}$

$$D = \frac{w_1 \times \rho}{w} \longrightarrow ①$$

$\because w = w_1 - w_2$

By putting the value of w in eq① we get;

$$D = \frac{w_1 \times \rho}{w_1 - w_2}$$

$$D = \frac{w_1}{w_1 - w_2} \times \rho \longrightarrow ②$$

Thus, finding the weight of the solid in air w_1 and its weight in water w_2.

Density of the solid can be calculated by eq # 2.

Example 7.4 ***The weight of a metal spoon in air is 0.48 N. Its weight in water is 0.42 N. Find its density.***

Solution: Weight of the spoon $w_1 = 0.42$ N

Weight of spoon in water $w_2 = 0.40$ N

Density of water $\rho = 1000 \text{ kg m}^{-3}$

Denity of spoon $D = ?$

By using the given equation, we get;

$$D = \frac{w_1}{w_1 - w_2} \times \rho$$

$$= \frac{0.48\text{N}}{0.48\text{N} - 0.42\text{N}} \times 1000 \text{ kg m}^{-3}$$

$= 8000 \text{ kg m}^{-3}$

Thus, the density of the material of spoon is 8000 kg m^{-3}.

7.7 Principle of Floatation

Q14. What is the principle of floatation. Briefly explain it.

Ans. Principle of floatation:

A floating object displaces a fluid having weight equal to the weight of the object.

Explanation: Principle of floatation can be explained by the process of sinking and floating of any object.

Process of sinking of an object:

An object sinks if its weight is greater than the upthrust acting on it.

Process of floating of an object: An object floats if its weight is equal or less than the upthrust. When an object floats in a fluid, the upthrust acting on it is equal to the weight of the object.

In case of floating object, the object may be partially immersed.

The upthrust is always equal to the weight of the fluid displaced by the object.

This is the principle of floatation.

Importance of principle:

Principle of floatation is applicable on liquids as well as gases.

There are numerous applications of this principle in our daily life.

Example 7.5 ***An empty meteorological balloon weighs 80 N. It is filled with 10^3 cubic metres of hydrogen. How much maximum contents the balloon can lift besides its own weight? The density of hydrogen is 0.09 kg m^{-3} and the density of air is 1.3 kg m^{-3}.***

Solution: Weight of the balloon = $w = 80 \text{ N}$

Volume of hydrogen = $V = 10^3 \text{m}^3$

Density of hydrogen = $\rho_1 = 0.09 \text{ kg m}^{-3}$

Weight of hydrogen $w_1 = ?$

Density of air $\rho_2 = 1.3 \text{ kg m}^{-3}$

Weight of the contents $w_2 = ?$

Upthrust F = Weight of air displaced

$= \rho_2 V g$

$= 1.3 \text{ kg m}^{-3} \times 10 \text{ m}^3 \times 10 \text{ ms}^{-2} = 130 \text{ N}$

Weight of hydrogen $w_1 = \rho_1 V g$

$= 0.09 \text{ kg m}^{-3} \times 10 \text{ m}^3 \times 10 \text{ ms}^{-2} = 9 \text{ N}$

Total weight lifted $= w + w_1 + w_2$

To lift the contents, the total weight of the balloon should not exceed F.

Thus $w + w_1 + w_2 = F$

or $80\ N + 9\ N + w_2 = 130\ N$

or $w_2 = 130\ N - 89\ N = 41\ N$

Thus, the maximum weight of 41 N can be lifted by the balloon in addition to its own weight.

Q15. How does a wooden block float on water? What is the principle of ships, boats and submarines? Write a brief explanation.

Ans. According to the principle of floatation, a body floats if it displaces water equal to the weight of the body when it is partially or completely immersed in water.

Floatation of wooden block: A wooden block floats on water. It is because the weight of an equal volume of water is greater than the weight of the block.

Principle of ships and boats: Ships and boats are designed on the principle of floatation. They carry passengers and goods over water.

Floating of ships and boats: Ships and boats floats on water, it is because the weight of an equal volume of water is greater than the weight of ships and boats.

Sinking of ships and boats: Ships and boats would sink in water if its weight including the weight of its passengers and goods becomes greater than the upthrust of water.

Figure 7.20: A ship floating over water

Principle of submarine: A submarine can travel over as well as under water. It also works on the principle of floatation.

Floating of submarine: Submarine floats over water when the weight of the water equal to its volume is greater than its weight. Under this condition, it is similiar to a ship and remains partially above water level.

System of tanks: Submarine has a system of tanks which can be filled with and emptied from seawater.

Figure 7.21: A submarine travels under water

Sinking of submarine: When the tanks of submarine are filled with seawater, the weight of the submarine increases.

As soon as its weight becomes greater than the upthrust, it dives into water and remains under water.

To come up on the surface, the tanks are emptied from sea water.

Example 7.6 ***A barge, 40 metre long and 8 metre broad, whose sides are vertical, floats partially loaded in water. If 125000 N of cargo is added, how many metres will it sink?***

Solution: Area of the barge A $= 40\ m \times 8\ m$

$= 320\ m^2$

Additional load w to carry $= 125000\ N$

Increased upthrust F of water must be equal to the additional load. Hence

$$F = \rho Vg$$

Since $F = w$

$\therefore$ $\rho Vg = w$

Or $1000\ kg\ m^{-3} \times V \times 10\ ms^{-2} = 125000\ N$

Or $V = 12.5\ m^3$

Depth (h) to which barge sinks $= h = \dfrac{V}{A}$

$$\therefore \quad h = \frac{12.5m^3}{320m^2}$$

$$h = 0.04\ m = 4\ cm$$

Thus, the barge will sink 4cm on adding 125000 N cargo.

7.8 Elasticity

Q16.(a) How elasticity can be defined. Give a brief explanation.

(b) How stress and strain can be defined? Write their formulas and units.

Ans. (a) Elasticity: The property of a body to restore its original size and shape as the deforming force ceases to act is called elasticity.

Explanation by a simple case: The pointer of a spring balance is lowered when a body is suspended from it. It is because the length of the spring inside the balance increases depending upon the weight of the suspended body.

Example # 1:

A spring is stretched by a force as shown in figure (a).

Example # 2: A rod is twisted by the torque produced by a couple as shown in figure (b)

Example # 3: A strip is bent by a force as shown in figure.

Deforming force: The applied force that changes shape, length or volume of a substance is called deforming force.

Elastic object: In most of the cases, the object returns to its original size and shape as soon as the deforming force is removed. These objects are called elastic objects.

Figure 7.22: (a) A spring is stretched by a force (b) A rod is twisted by the torque produced by a couple (c) A strip is bent by a force.

(b) Stress: Stress is defined as the force acting on unit area at the surface of a body. Stress is related to the force producing deformation.

Formula or mathematical form: Stress can be found out by following formula.

$$\text{Stress} = \frac{\text{Force}}{\text{Area}}$$

$$\text{Stress} = \frac{F}{A}$$

Unit of stress: In SI, the unit of stress is newton per square metre (Nm^{-2}).

Strain: When stress acts on a body, it may change its length, volume, or shape. A comparison of such a change caused by the stress with the original length, volume or shape is called as strain.

Formula or mathematical form: Strain can be found out by following formula;

$$\text{Strain} = \frac{\text{Change in shape}}{\text{Original shape}}$$

Tensile strain: If stress produces a change in the length of an object then the strain is called tensile strain.

Formula of tensile strain: Tensile strain can be found out by following formula;

$$\text{Tensile strain} = \frac{\text{Change in length}}{\text{Original length}} = \frac{\Delta L}{L_o}$$

Unit of strain: Strain has no units as it is simply a ratio between two similar quantities.

7.9 Hooke's Law

Q17. How Hooke's law can be defined and explained? For what purpose Hooke's law is used? Define elastic limit also.

Ans. The strain produced in a body by the stress applied to it is directly proportional to the stress with in the elastic limit of the body is called Hooke's law.

Formula or mathematical form: Mathematically Hooke's law can be written as:

$$\text{stress} \propto \text{strain}$$

$$\text{stress} = \text{constant} \times \text{strain}$$

$$\frac{\text{stress}}{\text{strain}} = \text{constant}$$

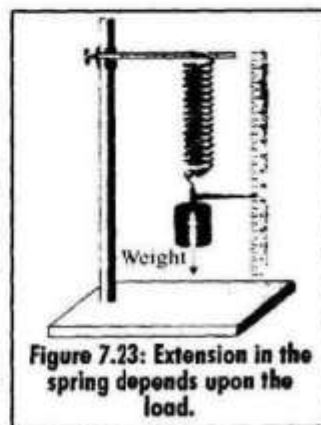
Example: Extension in the spring depends upon the load. This load and extension is directly proportional to each other.

Application of Hooke's law: Hooke's law is applicable to all kinds of deformation and all types of matter. i.e, solids, liquids or gases within certain limit. This limit tells the maximum stress that can be safely applied on a body without causing permanent deformation in its length, volume or shape.

Elastic limit: Elastic limit can be defined as a limit within which a body recovers its original length, volume or shape after the deforming force is removed.

Figure 7.23: Extension in the spring depends upon the load.

Graph between force and extension:

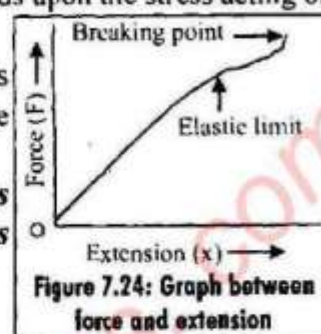
Graph between force and extension can be drawn as shown in the given figure.

Reason for the deformation of the body:

Deformation in length, volume or shape of a body depends upon the stress acting on the body.

When this stress crosses the elastic limit, a body is permanently deformed and is unable to restore its original state after the stress is removed.

Figure 7.24: Graph between force and extension

Q18. How Young's Modulus can be explained? Write its formula and unit. Also make a table which shows the Young's Modulus of different objects.

Ans. Young's Modulus can be explained and understood as;

Consider a long bar of length L_o and cross-sectional area A. Let an external force F equal to the weight w stretches it such that the stretched length becomes L.

Hooke's law: A ccording to Hooke's law, the ratio of stress to tensile strain is constant within the elastic limit of the body.

Young's Modulus: The ratio of stress to tensile strain is called as Young's modulus.

Formula or mathematical form:

Young's modulus can be written in mathematics as;

$$\text{Young's modulus (Y)} = \frac{\text{Stress}}{\text{Tensile strain}}$$

Let ΔL be the change in the length of the rod, then

$$\Delta L = L - L_o$$

$$\text{As we know; stress} = \frac{\text{Force}}{\text{Area}} = \frac{F}{A}$$

$$\text{Tensile strain} = \frac{\text{change in length}}{\text{original length}}$$

$$\text{Tensile strain} = \frac{L - L_o}{L_o} = \frac{\Delta L}{L_o}$$

$$Y = \frac{\text{Stress}}{\text{Tensile strain}} \longrightarrow (1)$$

By putting the values of stress and tensile strain in eq (1)

$$Y = \frac{F/A}{\Delta L/L_o}$$

$$Y = \frac{F}{A} \div \frac{\Delta L}{L_o}$$

$$Y = \frac{F}{A} \times \frac{L_o}{\Delta L}$$

$$Y = \frac{FL_o}{A\Delta L}$$

SI unit of Young's modulus:

The SI unit of Young's modulus is newton per square metre Nm^{-2}.

Young's modulus of some common materials:

Material	Young's modulus $\times 10^9\ Nm^{-2}$	Material	Young's modulus $\times 10^9\ Nm^{-2}$
Aluminum	70	Bone	0.02
Brass	91	Copper	110
Diamond	1120	Glass	60
Iron	190	Lead	16
Nickel	200	Rubber	0.0007
Steel	200	Tungsten	400
Wood (parallel gain)	10	Wood (perpendicular gain)	1

Example 7.7 ***A steel wire of cross-sectional area $5 \times 10^{-5} m^2$ is stretched through 1mm by a force of 10,000N. Find the Young's modulus of the wire. The length of the steel wire is 1m.***

Solution: Force $F = 10,000\ N$

Length $L_o = 1m$

Extension $\Delta L = 1mm = 0.001m$

Cross sectional Area $A = 5 \times 10^{-5} m^2$

Since $Y = \frac{FL_o}{A\Delta L}$

$$Y = \frac{10000\ N \times 1\ m}{5 \times 10^{-5} m^2 \times 0.001 m}$$

$$Y = 2 \times 10^{11}\ N\ m^{-2}$$

Thus, Young's modulus of steel is $2 \times 10^{11}\ N\ m^{-2}$.

SUMMARY

- Kinetic molecular model explains the three states of matter assuming that:
  - matter is made up of particles called molecules.
  - the molecules remain in continuous motion.
  - molecules attract each other.
- At very high temperature, the collision between atoms and molecules tears off their electrons. Atoms become positive ions. This ionic state of matter is called

plasma-the fourth state of matter.

- Density is the ratio of mass to volume of a substance. Density of water is 1000 kg m^{-3}.
- Pressure is the normal force acting per unit area. Its SI unit is Nm^{-2} or pascal (Pa).
- Atmospheric pressure acts in all directions.
- The instruments that measure atmospheric pressure are called barometers.
- The atmospheric pressure decreases as we go up. Thus, knowing the atmospheric pressure of a place, we can determine its altitude.
- The changes in atmospheric pressure at a certain place indicate the expected changes in the weather conditions of that place.
- Liquids also exert pressure given by: $P = \rho g h$
- Liquids transmit pressure equally in all directions. It finds application in everyday life. This is called Pascal's law.
- When a body is immersed wholly or partially in a liquid, it loses its weight equal to the weight of the liquid displaced. This is known as Archimedes principle.
- For an object to float, its weight must be equal or less than the upthrust of the liquid acting on it.
- The property of matter by virtue of which matter resists any force which tries to change its length, shape or volume, is called elasticity.
- Stress is the deforming force acting per unit area.
- The ratio of change of length to the original length, is called tensile strain.
- Young's modulus is the ratio between stress and tensile strain.

SOLVED QUESTIONS

7.1 Encircle the correct answer from the given choices:

(i) In which of the following state molecules do not leave their position?
(a) solid (b) liquid (c) gas (d) plasma

(ii) Which of the substances is the lightest one?
(a) copper (b) mercury (c) aluminum (d) lead

(iii) SI unit of pressure is pascal, which is equal to:
(a) 10^4 Nm^{-2} (b) 1 Nm^{-2} (c) 10^2 Nm^{-2} (d) 10^3 Nm^{-2}

(iv) What should be the approximate length of a glass tube to construct a water barometer?
(a) 0.5 m (b) 1 m (c) 2.5 m (d) 11 m

(v) According to Archimedes, upthrust is equal to:
(a) weight of displaced liquid (b) volume of displaced liquid
(c) mass of displaced liquid (d) none of these

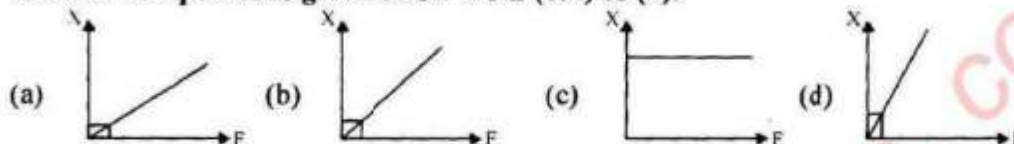
(vi) The density of a substance can be found with the help of:
(a) Pascal's law (b) Hooke's law

(c) Archimedes principle (d) Principle of floatation

(vii) According to Hooke's law

(a) stress × strain = constant (b) stress / strain = constant

(c) strain / stress = constant (d) stress = strain

The following force-extension graphs of a spring are drawn on the same scale. Answer the questions given below from (viii) to (x).

(a) (b) (c) (d)

(viii) Which graph does not obey Hooke's law?

(a) (b) (c) (d)

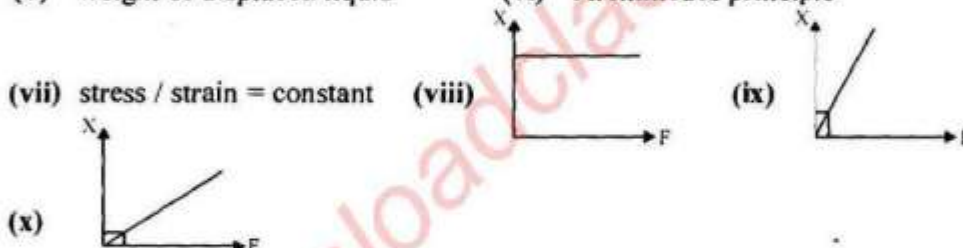
(ix) Which graph gives the smallest value of spring constant?

(a) (b) (c) (d)

(x) Which graph gives the largest value of spring constant?

(a) (b) (c) (d)

Ans: **(i)** solid **(ii)** aluminum **(iii)** 1 Nm^{-2} **(iv)** 11 m

(v) weight of displaced liquid **(vi)** Archimedes principle

(vii) stress / strain = constant **(viii)** **(ix)**

(x)

7.2 How is kinetic molecular model of matter helpful in differentiating various states of matter?

Ans. See Q. No. 1.

7.3 Does there exist a fourth state of matter? What is that?

Ans. Yes, there exist a fourth state of matter that is called plasma.

At very high temperature, the matter assumes the state of ions and electrons this is called plasma.

7.4 What is meant by density? What is its SI unit?

Ans. Density of a substance is defined as the mass per unit volume.

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

$$d = \frac{m}{V}$$

The SI unit of density is kilogramme per cubic metre (kg m^{-3}).

7.5 Can we use a hydrometer to measure the density of milk?

Ans. Hydrometer is a device which is used to measure the density of fluid. As the hydrometer is a glass tube with a scale marked on its stem and heavy weight in the bottom. It is partially immersed in the milk that is also a fluid, the density of which is to be measured, hence we can use hydrometer to measure the density of milk.

7.6 Define the term pressure.

Ans. The force acting normally on unit area at the surface of a body is called pressure.

$$\text{Pressure} = \frac{\text{force}}{\text{area}}$$

$$P = \frac{F}{A}$$

In SI, the unit of pressure is newton per square metre (Nm^{-2}).

7.7 Show that atmosphere exerts pressure.

Ans. See Q. No. 5.

7.8 It is easy to remove air from a balloon but it is very difficult to remove air from a glass bottle. Why?

Ans. It is very difficult to remove air from a glass bottle because air pressure in the bottle is less than atmospheric pressure.

7.9 What is a barometer?

Ans. The instrument that measures atmospheric pressure is called barometer. One of the simple barometer is mercury barometer.

7.10 Why is water not suitable to be used in a barometer?

Ans. As we know that mercury is 13.6 times more dense than water, Atmospheric pressure can hold vertical column of water about 13.6 times greater than the height of mercury column at that place. Thus, at sea level vertical height of water column would be $0.76m \times 13.6 = 10.34m$. Thus, we would need a glass tube more than 10m long or approximately 11m to make a water barometer that is too long, therefore water is not suitable to be used in barometer.

7.11 What makes a sucker pressed on a smooth wall sticks to it?

Ans. A wall sucker sticks to wall because of the difference in pressure between wall and rubber sucker which causes adhesion. This sucker sticks on the smooth wall or in other words the pressure on the outside becomes greater than the pressure on the inside.

7.12 Why does the atmospheric pressure vary with height?

Ans. As we know Earth's atmosphere extends upward about a few hundred kilometres with continuously decreasing density, and the pressure is directly proportional to the density, therefore as we going up, the atmospheric air becomes thinner and

thinner, so, density also reduces. Even at a height of about 30km, the atmospheric pressure becomes only 7mm of Hg, (mercury) which is approximately 1000 Pa. It would become zero at an altitude where there is no air.

7.13 What does it mean when the atmospheric pressure at a place fall suddenly?

Ans. A sudden fall in atmospheric pressure often followed by a storm, rain and typhoon to occur in few hours time.

7.14 What changes are expected in weather if the barometer reading shows a sudden increase?

Ans. If the barometer reading shows a sudden increase, or a rapid increase in atmospheric pressure, means that it will soon be followed by a decrease in the atmospheric pressure indicating poor weather ahead.

7.15 State Pascal's law.

Ans. Pressure applied at any point of a liquid enclosed in a container, is transmitted without loss to all other parts of liquid.

7.16 Explain the working of hydraulic press.

Ans. See Q. No. 10.

7.17 What is meant by elasticity?

Ans. Easticity is the property of matter by virtue of which matter resists any force which tries to change its length, shape or volume.

7.18 State Archimedes principle.

Ans. When an object is wholly or partially immersed in a liquid, it loses its weight equal to the weight of the liquid displaced. This is known as Archimedes principle.

7.19 What is upthrust? Explain the principle of floatation.

Ans. Upthrust is an upward force which acts on an object kept inside a liquid. It apparently makes the object to lose weight.

Principle of floatation: See Q. No. 14.

7.20 Explain how a submarine floats the water surface and dives down into water.

Ans. A submarine can travel over as well as under water. It works on the principle of floatation. It has a system of tanks which can be filled with and emptied from seawater. Submarine floats over water when the weight of the water equal to its volume is greater than its weight Under this condition, it is similar to a ship and remains partially above water level.

⇒ When the tanks of submarine are filled, the weight of the submarine increases. As soon as its weight becomes greater than the upthrust, it dives into water and remains under water.

7.21 Why does a piece of stone sink in water but a ship with a huge weight floats?

Ans. Ships and boats float on water. It is becausse the weight of an equal volume of

water is greater than the weight of ships and boats.

A stone sinks in water. It is because the weight of an equal volume of water is smaller than the weight of stone.

7.22 What is Hooke's law? What is meant by elastic limit?

Ans. **Hooke's law:** The strain produced in a body by the stress applied to it is directly proportional to the stress within the elastic limit of the body is called Hooke's law.

$$\text{stress} \propto \text{strain}$$

Elastic limit: Elastic limit can be defined as a limit within which a body recovers its original length, volume or shape after the deforming force is removed.

7.23 Take a rubber band. Construct a balance of your own using a rubber band. Check its accuracy by weighing various objects.

Ans. I took a rubber band. And constructed a balance of mine using a rubber band. Then i measured the weight of various objects to check its accuracy. First of all i took a lead pencil and measured its weight, then i put a small eraser on it and measured its weight.

Both the objects have less weight than the elastic limit of rubber band. That's why they could be measured easily.

I took a heavy stone and placed it in the balance.

But this mass was so heavy as compared to the elastic limit of the rubber band. Rubber band was broken and weight of the stone could not be measured.

SOLVED PROBLEMS

7.1 A wooden block measuring 40cm×10cm×5cm has a mass 850 g. Find the density of wood?

Data: Volume of block = $V = 40\text{cm} \times 10\text{cm} \times 5\text{cm} = 2000\text{cm}^3$

$$V = 2000\text{ cm}^3 = \frac{2000}{1000000} = 0.002\text{ m}^3$$

$$m = \text{mass of body} = 850\text{g} = \frac{850}{1000}$$

$$m = 0.85\text{ kg}$$

Required: Density = ρ = ?

Formula: $\text{Density} = \frac{\text{mass}}{\text{volume}} = \frac{m}{V}$

Solution: By putting values in given formula we get;

$$d = \frac{0.85}{0.002}$$

$$\boxed{d = 425\text{ kgm}^{-3}}$$

Answer: The required density of the wooden block is 425 kg m^{-3}.

7.2 What would be the volume of ice formed by freezing 1 litre of water?

Data: Volume of water = V_w = 1 litre

Required: Volume of ice = V_i = ?

Formula: As we know the basic relation;

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

Solution: As we know that:

1 litre of water volume has mass of 1 kg and density is 1000 kgm^{-3} of water.

So by using relation;

$$\text{density} = \frac{\text{mass}}{\text{volume}} = \frac{m}{V} \longrightarrow (1)$$

The density of ice is 0.92 times of the liquid water so,

density of ice = 1000 × 0.92 = 920 kgm^{-3}

and

volume of water = V_w = 1 litre

m = density × V_w = 1000 × 1

m = 1000 kg

By putting the value of (m) in equation (1);

$$V = \frac{m}{\rho} = \frac{1000}{920}$$

volume of ice = 1.09 litre

Answer: volume of ice = 1.09 litre.

7.3 Calculate the volume of the following objects:

i) An iron sphere of mass 5 kg, the density of iron is 8200 kgm^{-3}.

ii) 200 g of lead shot having density 11300 kgm^{-3}.

iii) A gold bar of mass 0.2 kg. The density of gold is 19300 kgm^{-3}.

Data. (i)

mass = m = 5kg

Density of iron = d = 8200 kgm^{-3}

Required: volume = ?

Formula: $\text{volume} = \frac{\text{mass}}{\text{density}}$

Solution: By putting the values we can get the value of volume:

$$\text{volume} = \frac{m}{d}$$

$$\text{volume} = \frac{5}{8200}$$

volume = 0.000609

$V = 6.09 \times 10^{-4}$

$\boxed{\text{volume} = 6.1\times10^{-4}\ m^3}$

(ii) Data:

$\text{mass} = 200g = \frac{200}{1000} = 0.2kg$

$\text{density} = d = 11300\ kgm^{-3}$

Required: volume = ?

Formula: $\text{volume} = \frac{\text{mass}}{\text{density}}$

Solution: By putting the values the volume can be found out.

$V = \frac{m}{d}$

$V = \frac{0.2\ kg}{11300\ kgm^{-3}}$

$V = 0.00001769$

$V = 1.769 \times 10^{-5}$

$\boxed{V = 1.77\times10^{-5} m^3}$

(iii) Data:

Mass = m = 0.2 kg

Density of gold = ρ = 19300 kgm^{-3}

Required: volume = V = ?

Formula: $\text{volume} = \frac{\text{mass}}{\text{density}}$

Solution: By putting the value in the formula, volume can be found out:

$V = \frac{m}{\rho}$

$V = \frac{0.2\ kg}{19300kgm^{-3}}$

$V = 0.000010362$

$\boxed{V = 1.04 \times 10^{-5} m^3}$

Answers: **(i)** The required volume of an iron sphere of mass 5kg is $6.1\times10^{-4}\ m^3$.

(ii) The required volume of a lead shot of mass 200g is $1.77\times10^{-5}\ m^3$.

(iii) The required volume of a gold bar of mass 0.2 kg is $1.04\times10^{-5}\ m^3$.

7.4 The density of air is 1.3 kgm⁻³. Find the mass of air in a room measuring 8m× 5m × 4m.

Data: Density of air = ρ = 1.3 kgm^{-3}

volume = 8m × 5m × 4m

volume = 160 m^3

Required: Mass of air = m = ?

Formula: Mass = density × volume

Solution: The mass of the air can be found out by putting the values in this formula

$m = 1.3 \times 160$

$\boxed{m = 208\ kg}$

Answer: The required mass of air is 208 kg.

7.5 A student presses her palm by her thumb with a force of 75N. What would be the pressure under her thumb having contact area 1.5 cm²?

Data: Force = F = 75 N

Contact area $= A = 1.5\ cm^2 = \frac{1.5}{(100)(100)} = \frac{1.5}{10000} = 0.00015 m^2$

Required: Pressure = P = ?

Formula: $P = \frac{F}{A}$

Solution: By using the value of force and area, pressure can be found by using formula.

$P = \frac{75\ N}{0.00015 m^2}$

$P = 500,000$

$P = 5 \times 100000$

$\boxed{P = 5 \times 10^5\ Nm^{-2}}$

Answer: The required pressure is $5 \times 10^5\ Nm^{-2}$.

7.6 The head of a pin is a square of side 10 mm. Find the pressure on it due to a force of 20 N?

Data: Force = F = 20 N

Length of side of the square = 10mm = 10×10^{-3} m

Area $= (10 \times 10^{-3})^2 m^2$

$A = 100 \times 10^{-6} m^2$

Required: Pressure = P = ?

Formula: $P = \frac{F}{A}$

Solution: By putting the values in above equation, pressure can be found out:

$P = \frac{20\ N}{100 \times 10^{-6} m^2}$

$P = \frac{20}{10^2 \times 10^{-6}}$

$P = \frac{20}{10^{-4}}$

$P = 20 \times 10^4$

$P = 2 \times 10 \times 10^4$

$\boxed{P = 2 \times 10^5 Nm^{-2}}$

Answer: The required pressure of the head pin is $2\times10^5 Nm^{-2}$.

7.7 ***A uniform rectangular block of wood 20 cm×7.5 cm×7.5cm and of mass 1000g stands on a horizontal surface with its longest edge vertical. Find (i) the pressure exerted by the block on the surface (ii) density of the wood?***

Data: Area of a rectangular wooden block $= A = 7.5cm \times 7.5cm$

$= 56.25$

$= 0.005625\ m^2$

mass of the block of wood = m = 1000g = 1kg

Height of the block = h = 0.075m

Required: **(a)** Find the pressure exerted by the block on the surface = P = ?

(b) Find the density of the wood = P = ?

Formula: As we know that:

$$\text{pressure} = \frac{\text{force}}{\text{area}} = \frac{F}{A}$$

$$\text{and density} = \frac{\text{mass}}{\text{volume}} = \frac{m}{V}$$

Solution:

(i) By using the above relation;

$$\text{pressure (P)} = \frac{F}{A} \text{ .... (I)}$$

As here force F = w = mg.

By substituting values; we get;

$F = w = 1 \times 10$ $\because$ 1000g = 1kg

Force = F = 10N

and Area of wooden block = $0.005625\ m^2$

By putting the values of area and force in eq (1).

$$P = \frac{10}{0.005625}$$

$\boxed{P = 1778\ Nm^{-2}}$

(ii) By using the relation;

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

$$\rho = \frac{m}{V} \text{ .... (II)}$$

volume = area × height

so, $V = 0.00525 \times 0.2$

$$\boxed{V = 1.125\times10^{-3}}$$

By putting values of mass and volume in equation (II)

$$\text{density}\ (\rho) = \frac{1\ \text{kg}}{1.125\times10^{-3}\text{m}^3}$$

$$= 0.88889 \times 10^3$$

$$= 888.89 \times 10^{-3} \times 10^3$$

$$\boxed{\rho = 888.89\ \text{kgm}^{-3}}$$

Answers: **(a)** Thus, Pressure exerted by the wooden block is 666.67 Pa

(b) Thus, Density of the wooden block is 889 kgm^{-3}

7.8 A cube of glass of 5cm side and mass 306g, has a cavity inside it. If the density of glass is 2.55g cm^{-3}. Find the volume of the cavity?

Data: The side of cube made by glass = h = 5 cm

The mass of glass cube = m = 306g

The density of glass is = ρ = 2.55 gcm^{-3}

Required: Volume of cavity = V = ?

Formula: As we know the very basic relation;

$$\text{denisty} = \frac{\text{mass}}{\text{volume}} = \frac{m}{V}$$

Solution: By using the basic formula;

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

For glass by putting values.

$$\rho = \frac{\text{mass}}{\text{volume}}$$

density × volume = mass

$2.55 \times (5 \times 5 \times 5) = \text{mass}$ $\quad\because$ volume = $5 \times 5 \times 5$

so, mass = 2.55×125

$$\boxed{\text{mass} = 318.75\text{g}}$$

Now the mass due to cavity is 306g

So, mass of cavity = 318.75 – 306g

$$\boxed{\text{mass of cavity} = 12.75\text{g}}$$

Now, we have to find out volume of the cavity;

$$\text{volume} = \frac{\text{mass}}{\text{density}}$$

By putting values of mass and density, we get;

$$\text{volume} = \frac{12.75}{2.55}$$

$$\boxed{\text{volume of cavity} = 5\text{cm}^3}$$

Answer: Hence the volume of cavity is 5cm^3

7.9 An object has weight 18N in air. Its weight is found to be 11.4N when immersed in water. Calculate its density. Can you guess the material of the object?

Data: weight of an object in air = w_a = 18N

weight of the same object in water = w_w = 11.4N

density of water = ρ_w = 1000 kgm^{-3}

Required: (a) density = ρ = ?

(b) material = ?

Formula: As we know the relation

$$\text{density of the object} = \left(\frac{\text{Weight of object in air}}{\text{Weight of object in air} - \text{weight of object in water}}\right) \times \rho$$

$$\text{density of the object} = \left(\frac{w_a}{w_a - w_w}\right) \times \rho_w$$

Solution: As we know that, the required relation is

$$\text{density of the object} = \left(\frac{w_a}{w_a - w_w}\right) \times \rho_w$$

By putting values;

$$\text{density of the object} = \frac{18}{(18 - 11.4)} \times 1000$$

$$\boxed{\text{density of the object} = 2727\ \text{kgm}^{-3}}$$

Answers: (a) The density of the object = 2727 kgm^{-3}

(b) This shows the material would be Aluminium because the exact density of Aluminium is very close to this value that is 2700 kgm^{-3}.

7.10 A solid block of wood of density 0.6g cm⁻³ weighs 3.06N in air. Determine (a) volume of the block (b) the volume of the block immersed when placed freely in a liquid of density 0.9 gcm⁻³?

Data: A solid block of wood have density = ρ = 0.6 g/cm^3

The same solid block weighs in air = w_a = 3.06N

Required: **(a)** Determine volume of the block = ?

(b) Determine the volume immersed when it is placed freely in a liquid of

density $0.9g/cm^3$ = ?

Formulas: By using following relation;

(a) $\text{density} = \frac{\text{mass}}{\text{volume}} = \frac{m}{V}$

(b) upthrust = F = w = ρVg

Solution: (a) First of all using the basic formula;

$$\text{density} = \frac{\text{mass}}{\text{volume}} = \frac{m}{V}$$

By rearranging the equation;

$$\text{volume} = \frac{\text{mass}}{\text{density}} = \frac{m}{\rho}$$

By substituting the values;

$$\text{volume} = \frac{\text{mass}}{0.6} \text{ .... (I)}$$

By using relation,

$$\text{mass} = \frac{\text{weight}}{g} = \frac{3.06}{10}$$

mass = 0.306 kg = 0.306 × 1000 = 306 g.

By putting the values of mass and volume in equation (I).

$$\text{volume} = \frac{306}{0.6}$$

$$\boxed{\text{volume} = 510\ cm^3}$$

(b) As we know the relation;

Upthrust force F = w = ρ V g .... (II)

as it is provided that = F = w = mg

F = w = 306 × 10

F = 3060 N

By putting values in eq II, we get;

3060 = (0.9) V (10)

$$V = \frac{3060}{0.9 \times 10}$$

$V = 340\ cm^3$

Answer: **(a)** Volume of block in the air = $510.4cm^3$

(b) Volume of block in the water = $340cm^3$

7.11 The diameter of the piston of a hydraulic press is 30cm. How much force is required to lift a car weighing 20 000 N on its piston if the diameter of the piston of the pump is 3 cm?

ta: The diameter of the piston of a hydraulic press is = d_2 = 30cm

A car to be lifted of weight = w = F_2 = 20,000 N

The diameter of piston = d_1 = 3cm

Required: How much force is required to lift the car = F_1 = ?

Formula: By using the application of Pascal's law as;

$$\frac{F_1}{a_1} = \frac{F_2}{A_2} \qquad (I)$$

$$\text{Area} = A = \pi r^2 = \frac{\pi}{4}d^2$$

So I becomes

$$\frac{F_1}{\frac{\pi}{4}d_1^2} = \frac{F_2}{\frac{\pi}{4}d_2^2}$$

$$F_1 = \frac{F_2}{d_2^2} \times d_1^2$$

$$F_1 = \frac{20,000}{(30 \times 10^{-2})^2} \times (3 \times 10^{-2})^2$$

$$= \frac{20000}{0.09} \times 0.0009$$

$$F_1 = 200 \text{ N}$$

Thus, the required force is 200 N.

7.12 A steel wire of cross-sectional area 2×10^{-5} m² is stretched through 2 mm by a force of 4000 N. Find the Young's modulus of the wire. The length of the wire is 2 m.

Data: A steel wire of cross-sectional area = A = 2×10^{-5}m²

The change in length after stretching = ΔL = 2mm

= 2×10^{-3}m.

The force applied for stretching = F = 4000 N.

The original length of the wire = L = 2m

Required: Young's modulus of the wire = Y = ?

Solution: By using the equation

$$\text{Young's modulus} = \frac{\text{stress}}{\text{strain}} \qquad \text{(I)}$$

we know that:

$$\text{stress} = \frac{\text{Force}}{\text{Area}}$$

$$\text{Stress} = \frac{F}{A}$$

and similarly;

$$\text{strain} = \frac{\text{change in length}}{\text{original length}}$$

$$\text{strain} = \frac{\Delta L}{L}$$

By putting the values of stress and strain in eq (1), we get;

$$\text{Young's modulus} = \frac{F/A}{\Delta L/L}$$

By rearranging the equation;

$$Y = \frac{F \times L}{A \times \Delta L}$$

By putting values in above equation.

$$Y = \frac{4000 \times 2}{2 \times 10^{-5} \times 2 \times 10^{-3}}$$

$$Y = \frac{\overset{2000}{\cancel{8000}}}{\cancel{4} \times 10^{-8}} = 2000 \times 10^{8} = 2 \times 10^{3} \times 10^{8} = 2 \times 10^{11}$$

$$\boxed{Y = 2 \times 10^{11} Nm^{-2}}$$

Answer: Hence the required Young's modulus = $Y = 2 \times 10^{11} Nm^{-2}$

OBJECTIVE TYPE QUESTIONS (MCQ'S+SHORT ANSWER) FROM PREVIOUS ANNUAL PAPERS OF ALL SECONDARY BOARDS
(LAHORE, GUJRANWALA, FAISALABAD, MULTAN, SAHIWAL, SARGODHA, RAWALPINDI, D.G. KHAN And BAHAWALPUR)

7.1 + 7.2	Kinetic Molecular Model of Matter + Density
7.3 + 7.4	Pressure + Atmospheric Pressure

☆ **Tick the correct answer.**

1. **In which of the following state molecules do not leave their position?** (LHR. GII)
   (A) Liquid (B) Solid (C) Gas (D) Plasma
2. **Which of the substance is the lightest one:** (SWL. GI, RWP. GI, DGK. GI, LHR. GI, SWL. GII)
   (A) copper (B) mercury (C) aluminium (D) lead
3. **One Litre is equal to:** (BWP. GI)
   (A) 1 $kgcm^{-3}$ (B) 1000 cm^{-3} (C) $10^{-6}m^3$ (D) $10^{-3}m^3$

4. SI unit of pressure is Pascal, which is equal to:
(LHR. GI, FBD. GI & GII, MLN. GI & GII, SGD. GI & GII, BWP. GI & GII, SWL. GI, DGK. GII)

(A) $10^4 Nm^{-2}$ (B) $1Nm^{-2}$ (C) $10^2 Nm^{-2}$ (D) $10^3 Nm^{-2}$

5. What should be the approximate length of a glass tube to construct a water barometer: (LHR. GII, FBD. GI, GRW. GII, MLN. GII, RWP. GI)

(A) 0.5m (B) 1m (C) 2.5m (D) 11m

Answers

1. Solid 2. aluminium 3. $10^{-3}m^3$ 4. $1Nm^{-2}$
5. 11m

☆ **Give short answer to the following questions.**

1. Write some important features of kinetic molecular model of matter.
(LHR. GI, MLN. GII, RWP. GII, DGK. GI, & GII, BWP. GI, FBD. GII, GRW. GI, SWL. GII,)

Ans. Kinetic theory has some important features.
- Matter is made up of particles called molecules.
- The molecules remain in continuous motion.
- Molecules attract each other.

2. How "Plasma" the fourth state of matter is formed?
(GRW. GII, RWP. GI, BWP. GI & GII)

Ans. Plasma: At very high temperature, the matter assumes the state of ions and electrons. This state is called plasma.

Formation of plasma: The kinetic energy of gas molecules goes on increasing if a gas is heated continuously. This causes the gas molecules to move faster and faster. The collisions between atoms and molecules of the gas become so strong that they tear off the atoms. Atoms lose their electrons and become positive ions. This ionic state of matter is called **plasma**.

3. Does there exist a fourth state of matter? If yes then what is that? (DGK. GI)

Ans. Yes, there exist a fourth state of matter that is called plasma.

At very high temperature, the matter assumes the state of ions and electrons this is called plasma.

4. The mass of 200cm³ of stone is 500 g, find its density. (LHR. GI)

Sol. $m = 500g$

$V = 200\ cm^3$

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

$$\text{Density} = \frac{500\ g}{200\ cm^3} = 2.5\ g\ cm^{-3}$$

Thus the density of stone is 2.5 g cm^{-3}

5. Can we use a hydrometer to measure the density of milk? (GRW. GI)

Ans. Hydrometer is a device which is used to measure the density of fluid. As the hydrometer is a glass tube with a scale marked on its stem and heavy weight in the bottom. It is partially immersed in the milk that is also a fluid, the density of which is to be measured, hence we can use hydrometer to measure the density of milk.

6. Write formula to find the density and its unit given in SI units.

(FBD. GII, SWL. GII, DGK. G I, & GII, GRW. GI, RWP. GI, & GII)

Ans. Density: Density of a substance is defined as the mass per unit volume.

Formula: $\text{density} = \frac{\text{mass}}{\text{volume}}$

$$d = \frac{m}{V}$$

Unit: The SI unit of density is kilogramme per cubic metre (kg m^{-3}).

7. Why water is not suitable to be used in a barometer? (LHR. GII)

Ans. As we know that mercury is 13.6 times more dense than water. Atmospheric pressure can hold vertical column of water about 13.6 times greater than the height of mercury column at that place. Thus, at sea level vertical height of water column would be 0.76m × 13.6 = 10.34m. Thus, we would need a glass tube more than 10m long or approximately 11m to make a water barometer that is too long, therefore water is not suitable to be used in barometer.

8. Define pressure. (GRW. GI & GII, FBD. GI, SWL. GI, SGD. GII, RWP. GI, BWP. GII, LHR. GI)

Ans. Pressure: The force acting normally on unit area at the surface of a body is called pressure.

Formula: $\text{Pressure} = \frac{\text{force}}{\text{area}}$

$$P = \frac{F}{A}$$

Unit: In SI, the unit of pressure is newton per square metre (Nm^{-2}).

9. Define the units of pressure. (FBD. GII)

Ans. The unit of pressure is pascal (Pa).

Pascal: Pressure is said to be one pascal if a force of one Newton is applied on an area of $1m^2$.

10. Why the air becomes thinner and thinner as we go up? (FBD. GI)

Ans. Earth's atmosphere extends upward about a few hundred kilometres with

continuously decreasing density. Nearly half of its mass is between sea level and 10 km. Up to 30 km from sea level contains about 99% of the mass of the atmosphere. The air becomes thinner and thinner as we go up.

11. What is barometer? (SWL. GI. DGK. GII)

Ans. Barometer: The instrument that measures atmospheric pressure is called barometer. One of the simple barometer is mercury barometer.

12. What changes are expected in weather if the barometer reading shows a sudden increase? (SGD. GI)

Ans. If the barometer reading shows a sudden increase, or a rapid increase in atmospheric pressure, means that it will soon be followed by a decrease in the atmospheric pressure indicating poor weather ahead.

13. What is meant by Atmospheric Pressure? (BWP. GII)

Ans. Atmosphere presssure: The Earth is surrounded by a cover of air called atmosphere. It extends to a few hundred kilometers above sea level. The pressure of atmosphere is called atmospheric pressure.

7.5 7.6	Pressure in Liquids Archimede's Principle
7.7 7.8 + 7.9	Principle of Floatation Elasticity + Hooke's Law

☆ **Tick the correct answer.**

1. _____ works on Pascal's law: (GRW. GI & GII, SWL. GI)

(A) screw gauge (B) vernier callipers (C) hydraulic press (D) wedge

2. The upthrust of liquid is given by: (SGD. GI, RWP. GI)

(A) ρgv (B) ρgh (C) ρgf (D) ρga

3. Liquid pressure at depth "h" is equal to: (DGK. GII)

(A) $\rho g h^2$ (B) $\rho g h^3$ (C) $\rho g h$ (D) $\rho g/h$

4. If forced will be applied on smaller area, pressure will become: (DGK. GI)

(A) Less (B) More (C) Zero (D) Much less

5. $\frac{\text{Stress}}{\text{Strain}}$ **= constant is:** (MLN. GI, FBD. GII)

(A) Pascal's Law (B) Newton's Law

(C) Archimedes Principle (D) Hooke's Law

6. **In SI system, the unit of Youngs modulus is:** (RWP. GII)

(A) Nm (B) Nm^{-1} (C) Nm^{-2} (D) Nm^{-3}

Answers

1. hydraulic press 2. ρgv 3. ρgh 4. More
5. Hooke's Law 6. Nm^{-2}

☆ **Give short answer to the following questions.**

1. **State the Pascal's Law.** (LHR. GI, GRW. GII, MLN. GII, SWL. GI)

Ans. Pascal's Law:

Pressure applied at any point of a liquid enclosed in a container, is transmitted without loss to all other parts of liquid.

2. **Write down any two examples of application of Pascal's Law.** (LHR. GII, SWL. GI, RWP. GII)

Ans. Pascal's law finds numerous application in our daily life. For example Automobiles, hydraulic brake system, hydraulic jack, hydraulic press etc.

3. **Define Archimedes principle.** (FBD. G II, SWL. G II, SGD. G II)

Ans. Archimedes principle: When an object is wholly or partially immersed in a liquid, it loses its weight equal to the weight of the liquid displaced. This is known as Archimedes principle.

4. **Why does the piece of stone sink in water but a ship with a huge weight floats?** (LHR. GII)

Ans. Ships and boats float on water. It is becausse the weight of an equal volume of water is greater than the weight of ships and boats.

A stone sinks in water. It is because the weight of an equal volume of water is smaller than the weight of stone.

5. **Explain how a submarine moves up the water surface and down into water?** (MLN. GII, BWP. GII)

Ans. A submarine can travel over as well as under water. It works on the principle of floatation. It has a system of tanks which can be filled with and emptied from seawater. Submarine floats over water when the weight of the water equal to its volume is greater than its weight Under this condition, it is similar to a ship and remains partially above water level.

When the tanks of submarine are filled, the weight of the submarine increases.

As soon as its weight becomes greater than the upthrust, it dives into water and remains under water.

6. **What is the principle of floatation?** (RWP. GII, MLN. GI, BWP. GI)

Ans. Principle of floatation:

A floating object displaces a fluid having weight equal to the weight of the object.

7. Define Elasticity. (MLN. GI, SGD. GI, RWP. GI, BWP. GII, SGD. GII)

Ans. Elasticity:

Easticity is the property of matter by virtue of which matter resists any force which tries to change its length, shape or volume.

8. Define Hooke's law and elastic limit. (GRW. GII)

Ans. Hooke's law: The strain produced in a body by the stress applied to it is directly proportional to the stress within the elastic limit of the body is called Hooke's law.

stress $\propto$ strain

Elastic limit:

Elastic limit can be defined as a limit within which a body recovers its original length, volume or shape after the deforming force is removed.

9. Define Young's Modulus. (MLN. GI, FBD. GI)

Ans. Young's Modulus:

According to Hooke's law, the ratio of stress to tensile strain is constant within the elastic limit of the body. "The ratio of stress to tensile strain is called as young's modulus".

10. What is the difference between Stress and Strain? (SGD. GI & GII, MLN. GI, BWP. GI)

Ans. Stress:

Stress is defined as the force acting on unit area at the surface of a body. Stress is related to the force producing deformation.

Strain:

When stress acts on a body, it may change its length, volume, or shape. A comparison of such a change caused by the stress with the original length, volume or shape is called as starin.

11. Define Hooke's Law and write its equation. (MLN. GII, SGD. GI)

Ans. Hooke's law:

The strain produced in a body by the stress applied to it is directly proportional to the stress within the elastic limit of the body is called Hooke's law.

stress $\propto$ strain

Equation: $\frac{\text{Stress}}{\text{Strain}} = \text{Constant}$

THERMAL PROPERTIES OF MATTER

STUDENTS LEARNING OUTCOMES

After studying this unit, the students will be able to:

- define temperature (as quantity which determine the direction of flow of thermal energy).
- define heat (as the energy transferred resulting from the temperature difference between two objects).
- list basic thermometric properties for a material to construct a thermometer.
- convert the temperature from one scale to another (Fahrenheit, Celsius and Kelvin scales).
- describe rise in temperature of a body in terms of an increase in its internal energy.
- define the terms heat capacity and specific heat capacity.
- describe heat of fusion and heat of vaporization (as energy transfer without a change of temperature for change of state).
- describe experiments to determine heat of fusion and heat of vaporization of ice and water respectively by sketching temperature-time graph on heating ice.
- explain the process of evaporation and the difference between boiling and evaporation.
- explain that evaporation causes cooling.
- list the factors which influence surface evaporation.
- describe qualitatively the thermal expansion of solids (linear and volumetric expansion).
- explain thermal expansion of liquids (real and apparent expansion).
- solve numerical problems based on the mathematical relations learnt in this unit.

Conceptual Linkage

This chapter is built on:
Temperature Scales —Science—IV
Evaporization-Science-V
Thermal Expansion —Science—VIII
This chapter leads to:
Thermodynamics —Physics—XI

INVESTIGATION SKILLS:

- demonstrate that evaporation causes cooling.

SCIENCE, TECHNOLOGY AND SOCIETY CONNECTION:

- explain that the bimetallic strip used in thermostat is based on different rate of expansion of different metals on heating.

- describe one everyday effect due to relatively large specific heat of water.
- list and explain some of the everyday applications and consequences of thermal expansion.
- describe the use of cooling caused by evaporation in refrigeration process without using harmful CFC.

Major Concepts:

Introduction: We use heat not only for cooking but also for doing other jobs. For example, changing heat to mechanical energy, electrical energy, etc. This can be done only if we have basic understanding about heat. Heat is an important concept in Physics. People have been trying to explain the nature of heat throughout the history of mankind. A quantitative study of thermal phenomena requires a careful definition of such important terms as **heat, temperature** and **internal energy**. In this unit, we shall discuss various concepts related to heat, temperature, measurements of temperature and various thermal phenomena.

Figure 8.1: Heat is needed for cooking

8.1 Temperature And Heat

Q.1. Define and explain following terms.

(i) Temperature *(ii) Heat* *(iii) Thermal equilibrium*
(iv) Thermal contact *(v) Internal energy*

Ans: (i) Temperature:

Temperature of a body is the degree of hotness or coldness of the body.

Explanation: A candle flame is hot and said to be at high temperature. Ice on the other hand is cold and is said to be at low temperature. Our sense of touch is a simple way to know about the hotness or coldness of body. But this is not a certain and reliable method.

It is needed by us to use a reliable and practicable method to determine the relative hotness or coldness of bodies, for that purpose the thermometer is used by us.

(ii) Heat: Heat is the energy that is transferred from one body to the other in thermal contact with each other as a result of the difference of temperature between them.

Explanation: When a hot body and a cold body come close to each other, the temperature of hot body is decreased and temperature of cold body is increased.

The form of energy that is transferred from a hot body to a cold body is called heat. Heat is also called as the energy in transit.

(iii) Thermal equilibrium: When two bodies of different temperatures are brought close to each other, the heat is released by hot body and is absorbed by cold body.

So thermal equilibrium is the condition in which two bodies attain same temperature.

Explanation: When a cup of hot tea or water is placed in a room, it cools down gradually.

It stops cooling as it reaches the room temperature. Thus, temperature determines the direction of flow of heat. Heat flows from a hot body to a cold body until thermal equilibrium is reached.

Do you know?

The crocus flower is a natural thermometer. It opens when the temperature is precisely 23°C and closes when the temperature drops.

(iv) Thermal contact: Thermal contact is defined as the contact area which is used in the transfer of heat. A direct contact of hot bodies with cold bodies has high thermal contact.

Explanation: To store ice in summer, people wrap it with cloth or keep it in wooden box or in thermos flask. In this way, they avoid the thermal contact of ice with its hot surrounding otherwise ice will soon melt away.

(v) Internal energy: Once heat enters a body, it becomes its internal energy and no longer exists as heat energy.

Definition: The sum of kinetic energy and potential energy associated with the atoms, molecules and particles of a body is called its internal energy.

Explanation: Internal energy of a body depends on many factors such as the mass of the body, kinetic and potential energies of molecules etc.

- **Kinetic energy:** Kinetic energy of an atom or molecule is due to its motion which depends upon the temperature.
- **Potential energy:** Potential energy of atoms or molecules is the stored energy due to intermolecular attractive force.

8.2 Thermometer

Q.2.(a) What is thermometer? What are the properties of a thermometric liquid?

(b) What is the construction of liquid-in-glass thermometer?

Ans:(a) Thermometer:

A device that is used to measure the temperature of a body is called thermometer.

Thermometric material: Common thermometers are generally made using some suitable liquid as thermometric material.

Properties of thermometric liquid:

A thermometric liquid should have the following properties.

1. It should be visible.
2. It should have uniform thermal expansion.
3. It should have a low freezing point.

Figure 8.2: A strip thermometer

4. It should have a high boiling point.
5. It should not wet glass.
6. It should be a good conductor of heat
7. It should have a small specific heat capacity.

Figure 8.3: A thermometer shows body temperature

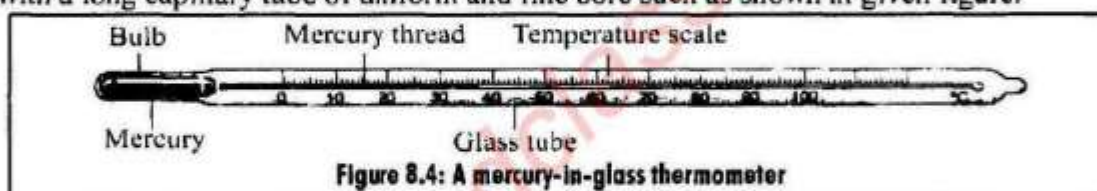
Properties of substances which change with temperature:

Some substances have property that changes with temperature. For example;

⇒ Substances expand on heating.
⇒ Substances change their colour on heating.
⇒ Substances change their electric resistance on heating.
⇒ The substances due to their thermal expansion, changes in the pressure of a gas, variation in the electrical resistance of a conductor, are used as thermometric material.

Ans: (b) Liquid -In-Glass Thermometer:

Construction of liquid-in-glass thermometer: A liquid-in-glass thermometer has a bulb with a long capillary tube of uniform and fine bore such as shown in given figure.

Figure 8.4: A mercury-in-glass thermometer

Thermometric material:

A suitable liquid is filled in the bulb as a thermometric material.

Expansion of thermometric material on heating: When temperature of the thermometric liquid increases, it expands and rises in the glass tube.

Function of a glass stem of thermometer:

The glass stem of a thermometer is thick and acts as a cylindrical lens.
This makes it easy to see the liquid level in the glass tube.

Properties of liquid mercury:

- Mercury freezes at -39°C and boils at 357°C.
- Mercury has all thermometric properties, which are necessary for thermometric material.

Uses of mercury in liquid-in-glass thermometer:

- Due to the wide importance of mercury, it is one of the most suitable liquid for the liquid-in-glass thermometers.
- Mercury-in-glass thermometers are widely used in laboratories, clinics and houses to measure temperatures in the range from -10°C to 150°C.

Thermometer scale:

A thermometer has a scale on its stem:

This scale has two fixed points.

(1) Lower fixed point

(2) Upper fixed point

Do you Know?

A clinical thermometer is used to measure the temperature of human body. It has a narrow range from 35°C to 42°C. It has a constriction that prevents the mercury to return. Thus, its reading does not change until reset.

(1) Lower fixed point:

The lower fixed point is marked to show the position of liquid in the thermometer when it is placed in ice.

(2) Upper fixed point: Upper fixed point is marked to show the position of liquid in the thermometer when it is placed in steam at standard pressure above boiling water.

Q.3. What are the scales of temperature? What are the types of scales which are commonly used in daily life?

Ans: Scale of temperature: A scale is marked on the thermometer. The temperature of the body in contact with the thermometer can be read on that scale.

Types of scales: Three scales of temperature are commonly used in daily life.

(1) Celsius scale or centigrade scale (2) Fahrenheit scale (3) Kelvin scale

(1) Celsius scale or centigrade scale (°C): Celsius scale is also called centigrade scale.

The interval between lower and upper fixed points is divided into 100 equal parts as shown in given figure (a)

Lower fixed point: The lower fixed point on the Celsius scale is marked as 0°C.

Upper fixed point: The upper fixed point on the Celsius scale is marked as 100°C.

(2) Fahrenheit scale (°F): On Fahrenheit scale, the interval between lower and upper fixed points is divided into 180 equal parts as shown in given figure (b).

Lower fixed point: The lower fixed point on the Fahrenheit scale is 32°F as shown in the figure (b)

Upper fixed point: The upper fixed point on the Fahrenheit scale is 212°F as shown in figure (b)

(3) Kelvin scale: On Kelvin scale, the interval between the lower and upper fixed points is divided into 100 equal parts as shown in figure (c). Thus, a change in 1°C is equal to a change of 1K.

Figure 8.5: Various scales of temperature

Lower fixed point:

The lower fixed point on the Kelvin scale is 273K as shown in figure (c)

Upper fixed point: The upper fixed point on the Kelvin scale is 373 K

Absolute zero:

The zero on the Kelvin scale is called the absolute zero and it is equal to -273°C.

Unit of temperature: In SI units, the unit of temperature is called Kelvin (K) and its scale is called Kelvin scale of temperature.

Q.4. How conversion of temperature from one scale to an other scale of temperature can be done? Write their formulas.

Ans: One scale of temperature can be converted into another scale by using following formulas.

Conversion of temperature from Celsius to Kelvin scale:

The temperature T on Kelvin scale can be obtained by adding 273 in the temperature C on Celsius scale Thus,

$$T(K) = 273 + C$$

Conversion of temperature from Kelvin to Celsius scale:

The temperature on Celsius scale can be found by subtracting 273 from the temperature in Kelvin Scale. Thus,

$$C = T(K) - 273$$

Do You Know?	
Sun's core	15 000 000°C
Sun's surface	6000°C
Electric lamp	2500°C
Gas lamp	1580°C
Boiling water	100°C
Human body	37°C
Freezing water	0°C
Ice in freezer	−18°C
Liquid oxygen	−180°C

Conversion of temperature from Celsius to Fahrenheit scale:

Since 100 divisions on Celsius scale are equal to 180 divisions on Fahrenheit scale.

Therefore, each division on Celsius scale is equal to 1.8 divisions on Fahrenheit scale.

Moreover, 0°C corresponds to 32°F.

$F = 1.8\,C + 32$

In this equation

F is the temperature on Fahrenheit scale.

C is the temperature on Celsius scale.

Conversion of temperature from Fahrenheit to Celsius scale:

To convert the temperature from Fahrenheit to Celsius scale, the given equation is used.

$$C = \frac{F - 32}{1.8}$$

Example 8.1 ***What will be the temperature on Kelvin scale of temperature when it is 20°C on Celsius scale?***

Solution: $C = 20°C$

as $T = 273 + C$

$T = 273 + 20 = 293K$

Example 8.2 ***Change 300K on Kelvin scale into Celsius scale of temperature.***

Solution: $T = 300K$

Since $C = T(K) - 273$

$\therefore$ $C = (300 - 273)°C$

or $C = 27°C$

Example 8.3 ***Convert 50°C on Celsius scale into Fahrenheit temperature scale.***

Solution: $C = 50°C$

Since $F = (1.8 \times C + 32)$

$F = (1.8 \times 50 + 32)$

or $F = 122°F$

Thus, 50°C on Celsius scale is 122°F on Fahrenheit scale.

Example 8.4 ***Convert 100°F into the temperature on Celsius scale.***

Solution: $F = 100°F$

Since $1.8C = F - 32$

$\therefore \quad = 100 - 32$

or $1.8C = 68$

or $C = 68/1.8$

or $C = 37.8°C$

Thus 100°F is equal to 37.8°C.

Mini Exercise:

1. **Which of the following substances have greater average kinetic energy of its molecules at 10°C?**
   (a) steel (b) copper (c) water (d) mercury

Ans: At 10°C water molecules have greater kinetic energy.

2. **Every thermometer makes use of some property of a material that varies with temperature. Name the property used in:**
   (a) strip thermometers (b) mercury thermometers

Ans: (a) Colour of substance changes on heating. In the strip thermometer colour of strip is changed on heating.
(b) Mercury has uniform thermal expansion, easily visible, has low freezing point, has high boiling point and less specific heat.
Due to these properties mercury is used in mercury thermometer.

8.3 Specific Heat Capacity

Q.5. What is specific heat capacity? Explain briefly. Write its formula and unit.

Ans: Specific heat: Specific heat of a substance is the amount of heat required to raise the temperature of 1kg mass of that substance through 1K.

Formula: To find out the specific heat, the following formula can be used.

$$c = \frac{\Delta Q}{m\Delta T}$$

In this equation:

ΔQ = the amount of heat absorbed by the body.

c = constant of proportionality or specific heat capacity.

m = mass of the object

ΔT = change in temperature.

SI unit of specific heat: In SI units,

- Mass 'm' is measured in kilogramme (kg)
- ΔQ is measured in joule (J)
- Temperature increase ΔT is taken in kelvin (K).

Hence,

Unut of specific heat in SI units is $Jkg^{-1}K^{-1}$

Explanation: When a body is heated, its temperature increases.

Amount of heat absorbed by a body depends on following factors.

(i) Mass (ii) Change in temperature

(i) Mass: It is observed that the quantity of heat ΔQ required to raise the temperature ΔT of a body is directly proportional to the mass 'm' of the body. Thus

$$\Delta Q \propto m \quad \rightarrow (i)$$

(ii) Change in temperature: Increase in the temperature of a body is found to be directly proportional to the amount of heat absorbed by it.

$$\Delta Q \propto \Delta T \quad \rightarrow (ii)$$

By combining these both factors, we get:

$$\Delta Q \propto m\Delta T$$

By changing the sign of proportionality into equality.

$$\Delta Q = c\, m\Delta T$$

c is the proportionality constant.

Specific heat of some common substances

Substance	*Specific heat $Jkg^{-1}K^{-1}$*	*Substance*	*Specific heat $Jkg^{-1}K^{-1}$*
Alcohol	2500.0	Aluminum	903.0
Bricks	900.0	Carbon	121.0
Clay	920.0	Copper	387.0
Ether	2010.0	Glass	840.0
Gold	128.0	Granite	790.0
Ice	2100.0	Iron	470.0
Lead	128.0	Mercury	138.6
Sand	835.0	Silver	235.0
Soil (dry)	810.0	Steam	2016.0
Tungsten	134.8	Turpentine	1760.3
Water	4200.0	Zinc	385.0

Q.6. What is the importance of large specific heat capacity of water? Write in detail.

Ans: The areas which are near to sea shore have moderate temperature:

Specific heat of water is 4200 $Jkg^{-1}K^{-1}$ and that of dry soil is about 810 $Jkg^{-1}K^{-1}$.

As a result the temperature of soil would increase five times more than the same mass of water by the same amount of heat.

Thus, the temperature of land rises and falls more rapidly than that of the sea. Due to above reason the areas near the sea shore have moderate temperature.

Do you Know?
The presence of large water reservoirs such as lakes and seas keep the climates of nearby land moderate due to the large heat capacity of these reservoirs.

Temperature variations near the sea:

Due to the large specific heat of water, the temperature variations from summer to winter are much smaller at places near the sea than land far away from the sea.

Use of water in a cooling system of automobile:

Water has a large specific heat capacity.

The cooling system of automobiles uses water to carry away unwanted thermal energy. In an automobile, large amount of heat is produced by its engine due to which its temperature goes on increasing. The engine would cease unless it is not cooled down.

Water circulating around the engine as shown by arrows in given figure maintains its temperature.

Figure 8.6: A Cooling system in automobile

Function of radiator in cooling system in automobile:

Water absorbs unwanted thermal energy of the engine and dissipates heat through its radiator in cooling system in automobile.

Use of water in central heating system: In central heating system such as shown in the figure, hot water is used to carry thermal energy through pipes from boiler to radiators.

These radiators are fixed inside the house at suitable places.

Figure 8.7: Central heating system.

Example 8.5 ***A container has 2.5 litres of water at 20°C. How much heat is required to boil the water?***

Solution: Volume of water = 2.5 litres

Mass of water $m = 2.5\ kg$

(Since density of water is $1000\ kgm^{-3}$ or $1 kg\ L^{-1}$)

Specific heat of water $c = 4200\ Jkg^{-1}K^{-1}$

Initial temperature $t_1 = 20°C$

Final temperature $t_2 = 100°C$

Increase in temperature $\Delta T = t_2 - t_1$

$= 100°C - 20°C$

$= 80°C$ or $80\ K$

Since $Q = cm\,\Delta T$

$\therefore$ $Q = 4200\ Jkg^{-1}K^{-1} \times 2.5kg \times 80k$

or $Q = 840\ 000\ J$

Thus required amount of heat is 840 000 J or 840 kJ.

Q.7. How heat capacity can be defined? Write its formula and unit also.

Ans: Heat capacity:

Heat capacity of a body is the quantity of thermal energy absorbed by it for one kelvin (1K) increase in its temperature.

Formula:

Heat capacity can be find out by given formula

$$\text{Heat capacity} = \frac{\Delta Q}{\Delta T} = \frac{mc\Delta T}{\Delta T}$$

$$\text{Heat capacity} = mc$$

In this equation

$\frac{\Delta Q}{\Delta T}$ is the heat capacity of the body.

ΔT is the change in temperature

ΔQ is the amount of heat which is absorbed by the body.

Heat capacity = mc:

This equation shows that capacity of a body is equal to the product of its mass of the body and its specific heat capacity.

Example:

Heat capacity of 5kg of water is $21000\ JK^{-1}$ ($5kg \times 4200\ Jkg^{-1}K^{-1}$). This means that 21000 joules of heat is required for every 1K rise in the temperature of water.

Relation of heat capacity with mass:

Mass and heat capacity are directly proportional to each other. Larger is the quantity of a substance, higher will be its heat.

8.4 Change of State

Q.8. How matter can be changed from one state to another. Give a diagrammatic explanation.

Ans: Matter can be changed from one state to another. For such a change to occur, thermal energy is added to or removed from a substance.

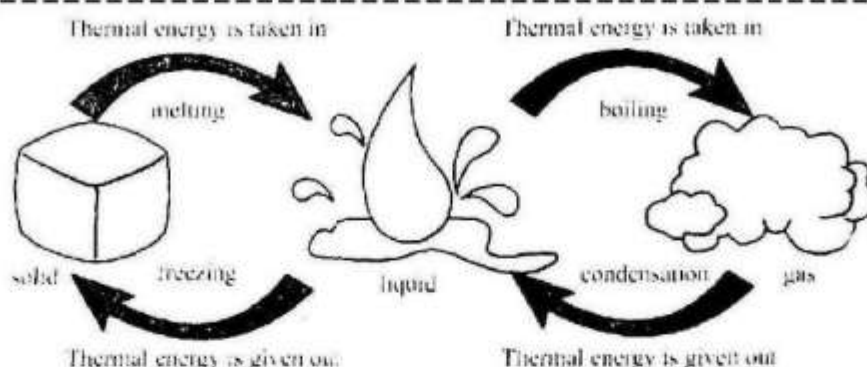



Figure 8.8: Heat energy brings about change of state in matter

Q.9. Show that water changes its states. Explain it with an activity.

Ans: Activity: Take a beaker and place it over a stand. Put small pieces of ice in the beaker and suspend a thermometer in the beaker to measure the temperature of ice.

Now place a burner under the beaker. The ice will start melting. The temperature of the mixture containing ice and water will not increase above 0°C until all the ice melts and we get water at 0°C. If this water at 0°C is further heated, its temperature will begin to increase above 0°C as shown by the graph in figure.

Part AB: On this portion of the curve, the temperature of ice increases from -30°C to 0°C.

Part BC: When the temperature of ice reaches 0°C, the ice water mixture remains at this temperature until all the ice melts.

Part CD: The temperature of the substance gradually increases from 0°C to 100°C. The amount of energy so added is used up in increasing the temperature of water.

Figure 8.9: A graph of temperature and time showing change of state of ice into water and steam.

Part DE: At 100°C water begins to boil and changes into steam. The temperature remains 100°C untill all the water changes into steam.

8.5 Latent Heat of Fusion

Q.10. What is latent heat of fusion? How it can be explained? Write formula also.

Ans: Latent heat of fusion: Heat energy required to change unit mass of a substance from solid to liquid state at its melting point without change in its temperature is called its latent heat of fusion denoted by H_f.

Explanation: For the explanation of latent heat of fusion following terms should be understood by us.

Melting or fusion: When a substance is changed from its solid state to liquid state by adding heat, the process is called melting or fusion.

Fusion point or melting point: The temperature at which a solid starts melting is called its fusion point or melting point.

Freezing point: When a liquid is cooled, it changes into solid state. The temperature at which a substance changes from liquid to solid state is called its freezing point.

Figure 8.10: Heating ice

Melting points of different substances:

Different substances have different melting points.

However, the freezing point of a substance is the same as its melting point.

Formula: $H_f = \Delta Q_f / m$ or

$\Delta Q_f = mH_f$

In this equation

'H_f' is the latent heat of fusion 'm' is the mass of the substance.

Latent heat of fusion of ice:

Ice changes at 0°C into water. Latent heat of fusion of ice is $3.36\times10^5\ \text{Jkg}^{-1}$. That is 3.36×10^5 joule heat is required to melt 1kg of ice into water at 0°C.

Q.11. How latent of fusion can be found out? Show it by simple experiment. Also draw a temperature time graph in this case.

Ans: Take a beaker and place it over a stand. Put small pieces of ice in the breaker and suspend a thermometer in the beaker to measure the temperature. Place a burner under the beaker. The ice will start melting. The temperature of the mixture containing ice and water will not increase above 0°C until all the ice melts. Note the time which the ice takes to melt completely into water at 0°C.

Continue heating the water at 0°C in the beaker. Its temperature will begin to increase. Note the time which the water in the beaker takes to reach its boiling point at 100°C from 0°C.

Figure 8.10: Heating ice

Draw a temperature-time graph such as shown in figure 8.11. Calculate the latent heat of fusion of ice from the data as follows:

Figure 8.11: Time- temperature graph as ice changes into water that boils as heating continues.

Let mass of ice $= m$

Finding the time from the graph:

Time taken by ice to melt completely at 0°C $= t_f = t_2 - t_1 = 3.6$ minutes

Time taken by water to heat from 0°C to 100°C $= t_o = t_3 - t_2 = 4.6$ minutes

Specific heat of water $= c = 4200\ \text{Jkg}^{-1}\text{K}^{-1}$

Increase in the temperature of water $= \Delta T = 100°C = 100\ K$

Heat required by water from 0°C to 100°C

$$= \Delta Q = m\, c\, \Delta T$$
$$= m \times 4200\ Jkg^{-1}K^{-1} \times 100\ K$$
$$= m \times 420\,000\ Jkg^{-1}$$
$$= m \times 4.2 \times 10^5\ Jkg^{-1}$$

Heat ΔQ is supplied to water in time t_o to raise its temperature from 0°C to 100°C. Hence, the rate of absorbing heat by water in the beaker is given by;

$$\text{Rate of absorbing heat} = \frac{\Delta Q}{t_o}$$

$$\therefore \text{Heat absorbed in time tf} = \Delta Q_f = \frac{\Delta Q \times t_f}{t_o}$$

$$= \Delta Q \times \frac{t_f}{t_o}$$

Since $\Delta Q_f = m \times H_f$ (from eq. 8.7)

Putting the values, we get;

$$m \times H_f = m \times 4.2 \times 10^5\ Jkg^{-1} \times \frac{t_f}{t_o}$$

or

$$H_f = 4.2 \times 10^5\ Jkg^{-1} \times \frac{t_f}{t_o}$$

The values of t_f amd t_o can be found from the graph. Put the values in the above equation to get;

$$H_f = 4.2 \times 10^5\ Jkg^{-1} \times \frac{3.6\ min}{4.6\ min}$$
$$= 3.29 \times 10^5\ Jkg^{-1}$$

The latent heat of fusion of ice found by the above experiment is $3.29 \times 10^5\ Jkg^{-1}$ while its actual value is $3.36 \times 10^5\ Jkg^{-1}$.

8.6 Latent Heat of Vaporization

Q.12. What is Latent heat of vaporization? Briefly describe. Make a table to show melting point, boiling point, heat of fusion and heat of vaporization of some common substances

Ans: Latent heat of vaporization: The quantity of heat that changes unit mass of a liquid completely into gas at its boiling point with out any change in its temperature is called its latent heat of vaporization denoted by H_v.

Explanation: When heat is given to a liquid at its boiling point, its temperature remains constant. The heat energy given to a liquid at its boiling point is used up in changing its

state from liquid to gas without any increase in temperature.

Formula: $H_v = \Delta Q_v / m$ or

$\Delta Q_v = mH_v$

In this equation

'H_v' is the latent heat of vaporization and 'm' is the mass of the substance.

Examlple: When water is heated, it boils at 100°C under standard pressure. Its temperature remains 100°C until it is changed completely into steam.

Latent heat of vaporization of water:

Latent heat of vaporization of water is $2.26\times10^6\,\text{Jkg}^{-1}$.

It means one kilogram of water requires 2.26×10^6 joule heat to change it completely into gas (steam) at its boiling point.

Tabular representation of melting point, boiling point, latent heat of fusion and latent heat of vaporization of some common substances.

Substance	Melting point (°C)	Boiling point (°C)	Heat of fusion (kJkg^{-1})	Heat of vaporization (kJkg^{-1})
Aluminium	660	2450	39.7	10500
Copper	1083	2595	205.0	4810
Gold	1063	2660	64.0	1580
Helium	-270	-269	5.2	21
Lead	327	1750	23.0	858
Mercury	-39	357	11.7	270
Nitrogen	-210	-196	25.5	200
Oxygen	-219	-183	13.8	210
Water	0	100	336.0	2260

Q.13. How latent heat of vaporization can be found out? Show it by simple experiment. Also draw temperature-time graph in this case.

Ans: At the end of experiment 8.1, the beaker contains boiling water. Continue heating water till all the water changes into steam. Note the time which the water in the beaker takes to change completely into steam at its boiling point 100°C.

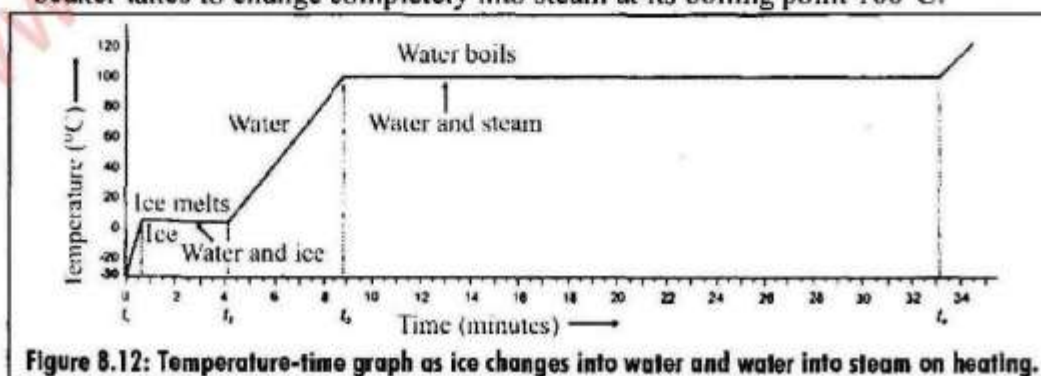



Figure 8.12: Temperature-time graph as ice changes into water and water into steam on heating.

Extend the temperature-time graph such as shown in figure. Calculate the latent heat of fusion of ice from the data as follows:

Let mass of ice $= m$

Time t_o taken to heat water from 0°C to 100°C (melt) $= t_o = t_3 - t_2 = 4.6$ minutes

Time taken by water at 100°C to change it into steam $= t_v = t_4 - t_3 = 24.4$ minutes

Specific heat of water $= c = 4200\ Jkg^{-1}K^{-1}$

Increase in the temperature of water $= \Delta T = 100°C$
$= 100\ K$

Heat required to heat water from 0°C to 100°C $= \Delta Q = mc\Delta T$

$$= m \times 4200\ Jkg^{-1}K^{-1} \times 100\ K$$

$$= m \times 420\ 000\ Jkg^{-1}$$

$$= m \times 4.2 \times 10^5\ Jkg^{-1}$$

As burner supplies heat ΔQ to water in time t_o to raise its temperature from 0°C to 100°C. Hence, the rate at which heat is absorbed by the beaker is given by

Rate of absorbing heat $= \dfrac{\Delta Q}{t_o}$

$\therefore$ Heat absorbed in time t_v $= \Delta Q_v = \dfrac{\Delta Q \times t_v}{t_o} = \Delta Q \times \dfrac{t_v}{t_o}$

Since $\Delta Q_v = m \times H_v$

Putting the values, we get

$$m \times H_v = m \times 4.2 \times 10^5\ Jkg^{-1} \times \frac{t_v}{t_o}$$

Or $H_v = 4.2 \times 10^5\ Jkg^{-1} \times \dfrac{t_v}{t_o}$

Putting the values of t_v and t_o from the graph, we get:

$$H_v = 4.2 \times 10^5\ Jkg^{-1} \times \frac{24.4\ min.}{4.6\ min.}$$

$$= 2.23 \times 10^6\ Jkg^{-1}$$

The latent heat of vaporization of water found by the above experiment is $2.23 \times 10^6\ Jkg^{-1}$ while its actual value is $2.26 \times 10^6\ Jkg^{-1}$.

8.7 The Evaporation

Q.14. What is evaporation and how evaporation process can be explained? What is the importance of evaporation.

Ans: Evaporation: Evaporation is the changing of a liquid into vapours (gaseous state) from the surface of a liquid without heating it.

Explanation: Take some water in a dish. The water in the dish will disappear after some time.

It is because the molecules of water are in constant motion and possess kinetic energy.

Fast moving molecules escape out from the surface of water and goes into the atmosphere. This is called evaporation. Evaporation process is shown in given figure.

Figure 8.13: Evaporation is escaping out of fast moving water molecules from the surface of liquid without heating

Difference between boiling and evaporation:

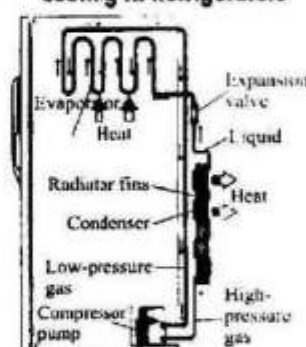
The process of evaporation takes place at all temperatures but only from the surface of a liquid while the process of boiling takes place at a certain fixed temperature which is the boiling point of that liquid.

Formation of vapours during boiling:

At boiling point, a liquid is changing into vapours not only from the surface but also from the entire volume of the liquid. These vapours come out of the boiling liquid as bubbles which break down on reaching the surface.

Importance of evaporation:

- Evaporation causes cooling in the atmosphere.
- Wet clothes dry up rapidly when spread only due to evaporation.
- Evaporation of perspiration helps to cool our bodies.
- Cooling is produced in refrigerators by evaporation of a gas into liquid.

Cooling In Refrigerators

Cooling is produced in refrigerators by evaporation of a liquid gas. This produces cooling effect. Freon, a CFC, was used as a refrigerant gas. But its use has been forbidden when it was known that CFC is the cause of ozone depletion in the upper atmosphere which results increase in amount of UV rays from the sun. The rays are harmful to all living matter. Freon gas is now replaced by Ammonia and other substances which are not harmful to the environment.

Q.15. How evaporation causes cooling? Explain.

Ans: As evaporation takes place, fast moving molecules escape out from the surface of the liquid.

Molecules that have lower kinetic energies are left behind. As a result the average kinetic energy of liquid molecules decreases. Since the temperature of a substance

depends on the average kinetic energy of its molecules, therefore the temperature of the liquid decreases.

Q.16. By which factors, rate of evaporation is affected? Explain all factors.

Ans: The rate of evaporation is affected by following factors.

(1) Temperature (2) Surface area (3) Wind (4) Nature of liquid

(1) Temperature:

Evaporation takes place at all temperature from the surface of a liquid.

Higher temperature has higher evaporation:

Evaporation is faster at high temperature than at low temperature.

Reason: At higher temperature, more molecules of a liquid are moving with high velocities. Thus more molecules are escaping from its surface.

Example: Wet clothes dry up more quickly in summer than in winter.

(2) Surface area: Larger is the surface area of a liquid, greater number of molecules has the chance to escape from its surface.

Example: Water evaporates faster when spread over large area.

(3) Wind: Wind blowing over the surface of a liquid sweeps away the liquid molecules that have just escaped out. It thus stops these molecules from returning to the liquid.

More wind more evaporation: Wind increases the rate of evaporation. This increases the chance for more liquid molecules to escape.

(4) Nature of the liquid: Liquids differ in the rate at which they evaporate.

Example: Put a few drops of ether or spirit on the palm, it evaporates rapidly while few drops of water on the palm does not evaporate rapidly.

Mini Exercise

1. How specific heat differs from heat capacity?

Ans: 1. Specific Heat:	Heat Capacity:
⇒ Specific heat of a substance is the amount of heat required to raise the temperature of 1K. ⇒ Specific heat can be found out by given relation. $c = \frac{\Delta Q}{m \Delta T}$ ⇒ SI unit of specific heat is $Jkg^{-1} K^{-1}$.	⇒ Heat capacity of a body is the quantity of thermal energy absorbed by it for one kelvin (1K) increase in its temperature. ⇒ The Heat capacity can be found out by given relation. Heat capacity = mc ⇒ Unit of heat capacity is JK^{-1}.

2. Give two uses of cooling effect by evaporation.

Ans: Uses of cooling effect by evaporation:

(i) Evaporation of perspiration helps to cool our bodies.

(ii) Cooling is produced in refrigerators by evaporation of liquefied gas. This produces cooling effect.

3. How evaporation differs from vaporization?

Evaporation: Evaporation is the changing of a liquid into vapours (gaseous state) from the surface of the liquid without heating it.

Vaporization: Vaporization is the changing of a liquid into vapours (gaseous state) from the surface of the liquid with heating it.

8.8 Thermal Expansion

Q.17. What is thermal expansion? How this process can be explained?

Ans: Thermal expansion: Expansion due to heating is called thermal expansion.

Expansion of objects due to heat: Most of the substances solids, liquids and gases expand on heating and contract on cooling.

The kinetic energy of the molecules of an object depends on its temperature.

The molecules of a solid vibrate with larger amplitude at high temperature than at low temperature.

Affect of heat on vibrations of molecules: On heating, the amplitude of vibration of the atoms or molecules of an object increases.

They push one another, farther away as the amplitude of vibration increases.

Result of thermal expansion: Thermal expansion results an increase in length, breadth and thickness of a substance.

Figure 8.14: Molecules of an object moving with (a) smaller amplitude at low temperature (b) larger amplitude at high temperature

Q18. Explain the linear thermal expansion in solids.

Ans: Linear thermal expansion:

The expansion in a solid upon heating is called linear thermal expansion.

Expansion of solids: It has been observed that solids expand on heating and their expansion is nearly uniform over a wide range of temperature.

Explanation: Consider a metal rod of length L_0 at certain temperature T_0. Let its length on heating the temperature T becomes L.

Thus,

Original length of the rod $= L_0$

Length of the rod after heating $= L$

Increase in length of the rod $= \Delta L = L - L_0$

like this;

Original temperature of the rod $= T_0$

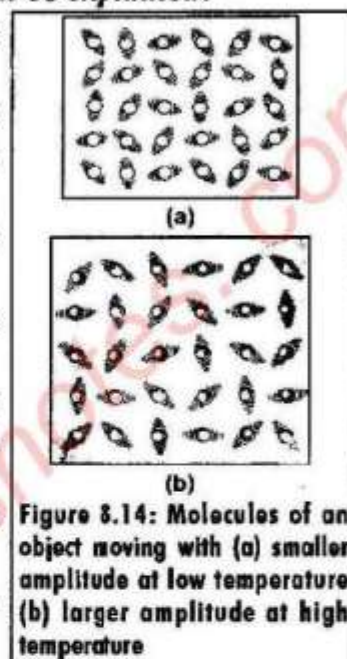
Temperature of the rod after heating $= T$

Increase in temperature $= \Delta T = T - T_0$

Factors on which linear expansion depends:

Linear expansion ΔL depends on two factors.

(i) Original length: It is found that change in length ΔL of a solid is directly proportional to its original length L_0.

$$\Delta L \propto L_0 \longrightarrow \text{(i)}$$

(ii) Change in temperature ΔT: It is found that change in length of a solid is directly proportional to change in temperature ΔT.

$$\Delta L \propto \Delta T \longrightarrow (ii)$$

By combining eq (i) and (ii), we have,

$$\Delta L \propto L_o \Delta T \longrightarrow (iii)$$

To change the sign of proportionality in to equality a constant is used.

So,

$$\Delta L = \alpha L_o \Delta T \longrightarrow (iv)$$

Co-efficient of linear thermal expansion: In this equation α is called the coefficient of linear thermal expansion of the substance.

Value of co-efficient of linear expansion can be found out by using following relation.

$$\alpha = \frac{\Delta L}{L_o \Delta T}$$

Definition of co-efficient of linear thermal expansion:

Co-efficient of linear thermal expansion $\propto$ of a substance can be defined as fractional increase in its length per kelvin rise in temperature.

Value of L: By using equation no (iv) we can determine the value of L as following.

$$\Delta L = \alpha L_o \Delta T$$

As we know:

$$\Delta L = L - L_o$$

So,

$$L - L_o = \alpha L_o \Delta T$$
$$L = L_o + \alpha L_o \Delta T$$
$$L = L_o(1 + \alpha \Delta T)$$

Values of co-efficient of linear thermal expansion:

Values of co-efficient of linear thermal expansion (α) of some substances are given in the following table:

Table 8.3: Coefficient of linear thermal expansion (α) of some common solids.

Substance	$\alpha(K^{-1})$	Substance	$\alpha(K^{-1})$
Aluminium	2.4×10^{-5}	Platinum	8.6×10^{-5}
Brass	1.9×10^{-5}	Tungsten	0.4×10^{-5}
Copper	1.7×10^{-5}	Glass (pyrex)	0.4×10^{-5}
Steel	1.2×10^{-5}	Glass (ordinary)	0.9×10^{-5}
Silver	1.93×10^{-5}	Concrete	1.2×10^{-5}
Gold	1.3×10^{-5}		

Example 8.6 ***A brass rod is 1m long at 0°C. Find its length at 30°C. (Coefficient of linear expansion of brass = $1.9\times10^{-5}\ K^{-1}$)***

Solution:

$$L_o = 1\ m$$
$$t = 30°C$$
$$t_o = 0°C$$
$$T_o = 0 + 273 = 273\ K$$
$$T = 30 + 273 = 303\ K$$
$$\Delta T = T - T_o$$
$$= 303\ K - 273\ K$$
$$= 30\ K$$
$$\alpha = 1.9\times10^{-5}\ K^{-1}$$
$$\text{since} = L = L_o(1 + \alpha\ \Delta T)$$
$$L = 1\ m\times(1 + 1.9\times10^{-5}\ K^{-1}\times 30\ K)$$
$$L = 1.00057\ m$$

Hence, the length of the brass bar at 30°C will be 1.00057 m.

Q19. Explain the volumetric thermal expansion.

Ans: Volume thermal expansion: The volume of a solid changes with the change in temperature and is called volume thermal expansion or cubical thermal expansion.

Explanation: Consider a solid of initial volume V_o at certain temperature T_o. On heating, the solid of a temperature T, let its volume becomes V, then.

Original volume of the solid = V_o
Volume of the solid after heating = V
Increase in volume of the solid = $\Delta V = V - V_o$

Like this: Original temperature of the solid = T_o
Temperature of the solid after heating = T
Increase in temperature of the solid = $\Delta T = T - T_o$

Factors on which volume expansion depends:

Volume expansion depends on two factors.

(i) Original volume: It is found that change in volume of a solid is directly proportional to its original volume V_o.

$$\Delta V \propto V_o \longrightarrow (i)$$

(ii) Change in temperature: It is found that change in volume of the solid is directly proportional to change in temperature ΔT.

$$\Delta V \propto \Delta T \longrightarrow (ii)$$

By Combining eq (i) and (ii), we have:

$$\Delta V \propto V_o\ \Delta T \longrightarrow (iii)$$

To change the sign of proportionality into equality a constant is used;

So,

$$\Delta V = \beta V_o \Delta T \longrightarrow \text{(iv)}$$

Co-efficient of volume thermal expansion: In this equation β is called the co-efficient of volume thermal expansion of the substance.

Value of co-efficient of volume thermal expansion can be found out by using following relation.

$$\beta = \frac{\Delta V}{V_o \Delta T}$$

Definition of co-efficient of volume thermal expansion:

The co-efficient of volume thermal expansion β can be defined as the fractional change in its volume per kelvin change in temperature.

Value of V: By using equation (iv) we can determine the value of V as following.

$$\Delta V = \beta V_o \Delta T$$

As we know;

$$\Delta V = V - V_o$$

So,

$$V - V_o = \beta V_o \Delta T$$
$$V = V_o + \beta V_o \Delta T$$
$$V = V_o (1 + \beta \Delta T).$$

Relation of linear expansion and volume expansion:

The co-efficients of linear expansion and volume expansion are related by the equation.

$$\beta = 3\alpha$$

Value of co-efficient of volume thermal expansion β for different substances are given in the following table:

Table 8.4: Coefficient of volume thermal expansion various substances.

Substance	β (K^{-1})	Substance	β (K^{-1})
Aluminium	7.2×10^{-5}	Glycerine	53×10^{-5}
Brass	6.0×10^{-5}	Mercury	18×10^{-5}
Copper	5.1×10^{-5}	Water	21×10^{-5}
Steel	3.6×10^{-5}	Air	3.67×10^{-3}
Platinum	27.0×10^{-5}	Carbon dioxide	3.72×10^{-3}
Glass (ordinary)	2.7×10^{-5}	Hydrogen	3.66×10^{-3}
Glass (pyrex)	1.2×10^{-5}		

Example 8.7 *Find the volume of a brass cube at 100°C whose side is 10cm at 0°C. (coefficient of linear thermal expansion of brass=$1.9\times10^{-5}K^{-1}$).*

Solution:

$L_o = 10cm = 0.1m$

$T_o = 0°C = (0 + 273) K = 273 K$

$T = 100°C = (100 + 273) K = 373 K$

$\Delta T = T - T_o$

$\Delta T = 373 K - 273 K = 100 K$

$\alpha = 1.9\times10^{-5}K^{-1}$

As $\beta = 3\alpha$

Therefore $\beta = 3\times1.9\times10^{-5}K^{-1} = 5.7\times10^{-5}K^{-1}$

Initial volume $V_o = L_o^3 = (0.1\ m)^3 = 0.001\ m^3 = 10^{-3}m^3$

Since $V = V_o(1+\beta\Delta T)$

Hence $V = 10^{-3}m^3\times(1+5.7\times10^{-5}K^{-1}\times100\ K)$

or $V = 10^{-3}m^3\times(1+5.7\times10^{-3})$

$= 10^{-3}m^3\times(1+0.0057)$

$= 1.0057\times10^{-3}m^3$

Hence, the volume of brass cube at 100°C will be $1.0057\times10^{-3}m^3$.

Q.20. What are the consequences of thermal expansion?

Ans: The expansion of solids may damage the bridges, railway tracks and roads as they are constantly subjected to temperature changes. So provision is made during construction for expansion and contraction with temperature.

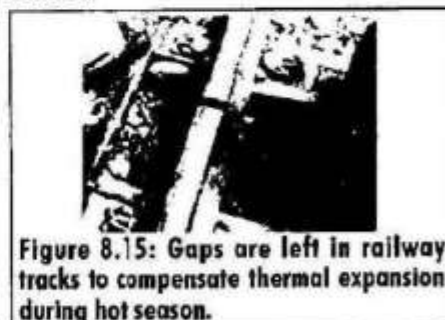



Figure 8.15: Gaps are left in railway tracks to compensate thermal expansion during hot season.

Expansion of railway track: Railway tracks buckled on a hot summer day due to expansion if gaps are not left between section.

Expansion of bridges: Bridges made of steel girders also expand during the day and contract during night. They will bend if their ends are fixed.

To allow thermal expansion, one end is fixed while the other end of the girder rests on rollers in the gap left for expansion.

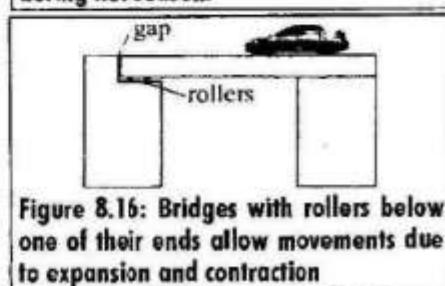



Figure 8.16: Bridges with rollers below one of their ends allow movements due to expansion and contraction

Overhead transmission lines:

Overhead transmission lines are given a certain amount of sag that they can contract in winter without snapping.

Figure 8.17: Wires on electric poles are given some sag to prevent breaking in winter.

Q.21. What are the applications of thermal expansion?

Ans: Thermal expansion is used in our daily life.

1. **For the measurement of temperature:**

In thermometers, thermal expansion is used in temperature measurements.

Opening the metallic cap of bottle:

To open the cap of a bottle that is tight enough, immerse it in hot water for a minute or so. Metal cap expands and becomes loose. It would now be easy to turn it to open.

3. **Joining of steel plates:**

To join steel plates tightly together, red hot rivets forced through holes in the plates as shown in figure.

The end of the hot rivet is then hammered. On cooling, the rivets contract and brings the plates tightly gripped.

Figure 8.18: (a) Hot rivets inserted. (b) after hammering, rivets are cold down.

4. **Fixing of iron rims:**

Iron rims are fixed on wooden wheels of carts.

Iron rims are heated. Thermal expansion allows them to slip over the wooden wheel. Water is poured on it to cool. The rim contracts and becomes tight over the wheel.

Q.22. How bimetal strips are constructed? How it works? Also write their uses.

Ans: Construction of bimetal strips:

A bimetal strip can be constructed by using two metals.

In a bimetal strip, two thin strips of different metals such as brass and iron are joined together as shown in given figure (a).

Bimetal strip: cold
Iron
(a)
Base

Figure 8.19 (a) A bimetal strip of brass and iron

Working of bimetal strip:

On heating the strip, brass expands more than iron. This unequal expansion causes bending of the strip as shown in the given figure (b).

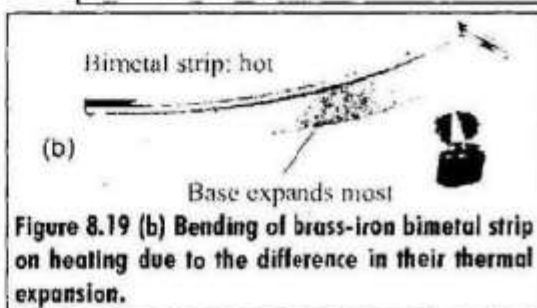



Figure 8.19 (b) Bending of brass-iron bimetal strip on heating due to the difference in their thermal expansion.

Uses of bimetal strips:

Bimetal strips are used for various purposes.

- Bimetal strips are used in thermometers to measure temperatures especially in furnaces and ovens.
- Bimetal strips are also used in thermostats. Bimetal thermostat switch is used to control the temperature of heater coil in an electric iron as shown in given figure.

Figure 8.20: Bimetal thermostat breaks the electrical circuit at preset temperature.

Q.23. What is thermal expansion of a liquid. Explain this process briefly.

Ans: Thermal expansion of liquid:

Expansion of a liquid upon heating is called the thermal expansion of liquid.

Process of liquid expansion:

The molecules of liquids are free to move in all directions within the liquid. On heating a liquid, the average amplitude of vibration of its molecules increases. The molecules push each other and need more space to occupy. This accounts for the expansion of the liquid when heated.

> **Do You Know?**
> Water on cooling below 4°C begins to expand until it reaches 0°C. on further cooling its volume increases suddenly as it changes into ice at 0°C. When ice is cooled below 0°C, it contracts i.e. its volume decreases like solids. This unusual expansion of water is called the anomalous expansion of water.

Greater thermal expansion in liquid: The thermal expansion in liquid is greater than solids due to the weak forces between their molecules. Therefore, the co-efficient of volume expansion of liquids is greater than solids.

Shape of liquid: Liquids have no definite shape of their own.

A liquid always attains shape of the container in which it is poured.

Types of thermal expansion for liquids:

When a liquid is heated, both liquid and the container undergo a change in their volume. So there are two types of thermal volume expansion for liquid.

- Apparent volume expansion
- Real volume expansion.

Q.24. How thermal expansion of a liquid can be determined? Explain with the help of experiment.

Ans: Take a long-necked flask. Fill it with some coloured liquid upto mark A on its neck as shown in figure. Now start heating the flask from bottom. The liquid level first falls to B and then rises to C.

The heat first reaches the flask which expands and its volume increases. As a result liquid descends in the flask and its level falls to B. After sometime the liquid begins to rise above B on getting hot. At certain temperature it reaches at C. The rise in level from A to C is due to the apparent expansion in the volume of the liquid. Actual expansion of

the liquid is greater than that due to the expansion because of the expansion of glass flask. Thus real expansion of the liquid is equal to the volume difference between A and C in addition to the volume expansion of the flask. Hence

Real expansion of the liquid = Apparent expansion of the liquid + Expansion of the flask.

or BC = AC + AB ....

The expansion of the volume of a liquid taking into consideration the expansion of the container also, is called the real volume expansion of the liquid. The real rate of volume expansion "β_r" of a liquid is defined as the actual change in the unit volume of a liquid for 1K (or 1°C) rise in its temperature. The real rate of volume expansion β_r is always greater than the apparent rate of volume expansion β_a by an amount equal to the rate of volume expansion of the container β_g. Thus,

$$\beta_r = \beta_a + \beta_g \text{ ....}$$

Figure 8.21: Real and apparent expansion of liquid.

It should be noted that different liquids have different coefficients of volume expansion.

SUMMARY

- The temperature of a body is the degree of hotness or coldness of the body.
- Thermometers are made to measure the temperature of a body or places.
- The lower fixed point is the mark that gives the position of mercury in the thermometer when it is placed in ice.
- The upper fixed point is the mark that shows the point of mercury in the thermometer when it is placed in steam from boiling water at standard pressure.
- Inter-conversion between scales:
  - From Celsius To Kelvin Scale:
    $$T(K) = 273 + C$$
  - From Kelvin to Celsius Scale:
    $$C = T(K) - 273$$
  - From Celsius to Fahrenheit Scale
    $$F = 1.8\,C + 32$$
- Heat is a form of energy and this energy is called heat as long as it is in the process of transfer from one body to another body. When a body is heated, the kinetic energy of its molecules increases, the average distances between the molecules increase.
- It has been observed that solids expand on heating and their expansion is nearly uniform over a wide range of temperature. Mathematically,
  $$L = L_o(1 + \alpha\Delta T)$$

- The thermal coefficient of linear expansion α of a substance is defined as the fractional increase in its length per kelvin rise in temperature.
- The volume of a solid changes with the change in temperature and is called as volume or cubical expansion.

$$V = V_0 (1 + \beta \Delta T)$$

- The thermal coefficient of volume expansion β is defined as the fractional change in its volume per kelvin change in temperature.
- There are two types of thermal volume expansion for liquids as well as for gases. Apparent volume expansion and real volume expansion.
- The specific heat of a substance is defined as the amount of heat required to raise the temperature of a unit mass of that substance through one degree centigrade (1°C) or one kelvin (1 K).
- The heat required by unit mass of a substance at its melting point to change it from solid state to liquid state is called the latent heat of fusion.
- The quantity of heat required by the unit mass of a liquid at a certain constant temperature to change its state completely from liquid into gas is called the latent heat of vaporization.

SOLVED QUESTIONS

8.1 Encircle the correct answer from the given choices:

(i) Water freezes at:
(a) 0°F (b) 32°F (c) –273 K (d) 0 K

(ii) Normal human body temperature is:
(a) 15°C (b) 37°C (c) 37°F (d) 98.6°C

(iii) Mercury is used as thermometric material because it has:
(a) uniform thermal expansion (b) low freezing point
(c) small heat capacity (d) all the above properties

(iv) Which of the following materials has large specific heat?
(a) copper (b) ice (c) water (d) mercury

(v) Which of the following materials has large value of temperature coefficient of linear expansion?
(a) Aluminum (b) Gold (c) Brass (d) Steel

(vi) What will be the value of β for a solid for which α has a value of $2\times10^{-5}K^{-1}$?
(a) $2\times10^{-5}K^{-1}$ (b) $6\times10^{-5}K^{-1}$ (c) $8\times10^{-15}K^{-1}$ (d) $8\times10^{-5}K^{-1}$

(vii) A large water reservoir keeps the temperature of nearby land moderate due to:
(a) low temperature of water (b) Low specific heat of water

(c) Less absorption of heat (d) Large specific heat of water

(viii) Which of the following affects evaporation?

(a) Temperature (b) Surface area of the liquid (c) Wind (d) All of the above

Ans: **(i)** 32°F **(ii)** 37°C **(iii)** all the above properties **(iv)** water
(v) Aluminum **(vi)** $6\times10^{-5}K^{-1}$ **(vii)** large specific heat of water
(viii) All of above

8.2 Why does heat flow from hot body to cold body?

Ans: Heat flows from hot body to cold body to attain the condition of thermal equilibrium.

8.3 Define the terms heat and temperature.

Ans: ***Heat:*** Heat is the energy that is transferred from one body to the other in thermal contact with each other as a result of the difference of temperature between them.

Temperature: Temperature of a body is the degree of hotness or coldness of the body.

8.4 What is meant by internal energy of a body?

Ans: The sum of kinetic energy and potential energy associated with the atoms, molecules and particles of a body is called its internal energy.

8.5 How does heating affect the motion of molecules of a gas?

Ans: By heating the gas, its molecules get high kinetic energy and start to collide more randomly. And motion of gas molecules is increased by heating. So pressure of gas molecules increase by heating.

8.6 What is a thermometer? Why mercury is preferred as a thermometric substance?

Ans: A thermometer is a device which is used to measure the temperature of a body.

Mercury is preferred as a thermometric substance due to following properties.

- It is easily visible.
- It has uniform thermal expansion.
- It has low freezing point and high boiling point.
- It has a small specific heat capacity.

8.7 Explain the volumetric thermal expansion.

Ans: See Q # 19

8.8 Define specific heat. How would you find the specific heat of a solid?

Ans: The specific heat of a substance is the amount of heat required to raise the temperature of 1kg mass of that substance through 1K.

Specific heat of any substance can be found out by using following formula:

$$c = \frac{\Delta Q}{m\Delta T}$$

c is the specific heat capacity

ΔQ is the amount of heat absorbed by the body

m is the mass of the body.

ΔT is the change of temperature

8.9 Define and explain latent heat of fusion.

Ans: See Q # 10

8.10 Define latent heat of vaporization.

Ans: The quantity of heat that changes unit mass of a liquid completely into gas at its boiling point without any change in its temperature is called its latent heat of vaporization denoted by H_v.

$$H_v = \frac{\Delta Qv}{m}$$

8.11 What is meant by evaporation? On what factors the evaporation of a liquid depends? Explain how cooling is produced by evaporation.

Ans: **Evaporation:** Evaporation is the changing of a liquid into vapours (gaseous state) from the surface of the liquid without heating it.

Factors which affect on evaporation:

The rate of evaporation is affected by the following factors.

(i) Temperature (ii) Surface area

(iii) Wind (iv) Nature of the liquid

Evaporation causes cooling:

As evaporation takes place, fast moving molecules escape out from the surface of the liquid. Molecules that have lower kinetic energies are left behind.

This lowers the average kinetic energy of the liquids molecules and the temperature of the liquid. Since temperature of a substance depends on the average kinetic energy of its molecules, therefore the temperature of the liquid decreases.

SOLVED PROBLEMS

8.1 Temperature of water in a beaker is 50°C. What is its value in Fahrenheit scale?

Data: Temperature = C = 50°C

Required: Value of temperature in Fahrenheit scale = ?

Formula: F = 1.8C + 32

Solution: By putting the value of C in the formula we get:

$$F = (1.8)(50) + 32$$

$$F = 90 + 32$$

$$\boxed{F = 122°F}$$

Answer: The required temperature of water in Fahrenheit scale is 122°F.

8.2: Normal human body temperature is 98.6°F. Convert it into Celsius scale and Kelvin scale.

Data: Temperature = F = 98.6°F

Required: Temperature in centigrade = °C = ?

Temperature in kelvin = TK = ?

Formulas: F = 1.8C + 32

T (K) = 273 + t°C

Solution: (i) F = 1.8C + 32

98.6 = 1.8C + 32

98.6 − 32 = 1.8 C

66.6 = 1.8C

66.6/1.8 = C

C = 37°C

(ii) T (K) = 273 + °C

T (K) = 273 + 37

T (K) = 310 K

Answers:(i) The required normal human body temperature in centigrade scale is 37°C.

(ii) The required normal human body temperature in Kelvin is 310 K.

8.3 Calculate the increase in the length of an aluminum bar 2m long when heated from 0°C to 20°C. The thermal coefficient of linear expansion of aluminum is $2.5\times10^{-5}K^{-1}$.

Data: Original length = L_o = 2m

Initial temperature = t_1 = 0°C

Final temperature = t_2 = 20°C

Original temperature = T_1 = 0°C = 0 + 273 = 273 K

Heating temperature = T_2 = 20°C = 20 + 273 = 293 K

Thermal co-efficient of linear expansion = α = $2.5\times10^{-5}K^{-1}$

Required: Increase in lenght = ΔL = ?

Formula: $\alpha = \frac{\Delta L}{L_o \Delta T}$

Solution: By rearranging the equation:

$L_o \Delta T \alpha = \Delta L$

By putting the values, in the equation; we get

$\Delta L = (2)(2.5)\times10^{-5})(T_2 - T_1)$

$\Delta L = (2)(2.5)\times10^{-5}(293\text{ K} - 273\text{ K})$

$\Delta L = 5\times10^{-5}(20)$

$\Delta L = 5\times20\times10^{-5}$

$\Delta L = 100\times10^{-5}$

$\Delta L = 100 \times 10^{-3} \times 10^{-2}$ m

$\Delta L = 0.1$cm

Answer: The required increase in length in aluminum bar is 0.1 cm.

8.4 A balloon contains 1.2m³ air at 15°C. Find its volume at 40°C. Thermal coefficient of volume expansion of air is $3.67 \times 10^{-3} K^{-1}$.

Data: Original volume $= V_o = 1.2m^3$

Initial temperature $= t_1 = 15°C$

Initial temperature $= T_1 = 15 + 273$

Initial temperature $= T_1 = 288$ K

Final temperature $= t_2 = 40°C$

Final temperature $= T_2 = 40 + 273$

Final temperature $= T_2 = 313$ K

Thermal co-efficient of volume expansion of air $= \beta = 3.67 \times 10^{-3} K^{-1}$

Change in temperature $= \Delta T = T_2 - T_1$

$= 313 - 288$

$\Delta T = 25$ K

Required: Increase in volume = V = ?

Formula: $V = V_0 (1 + \beta\Delta T)$

Solution: By putting the values in this formula, value of volume can be found out.

$V = 1.2 [1 + 3.67 \times 10^{-3} (25)]$

$V = 1.2 [1 + 91.75 \times 10^{-3}]$

$V = 1.2 [1 + 9.175 \times 10 \times 10^{-3}]$

$V = 1.2 [1 + 9.175 \times 10^{-2}]$

$V = 1.2 [1 + 0.09175]$

$V = 1.2 [1.09175]$

$V = 1.3101 \text{ m}^3$

Answer: The required volume of balloon is 1.3m³.

8.5 How much heat is required to increase the temperature of 0.5 kg of water from 10°C to 65°C?

Data: Mass of water $= m = 0.5$ kg

Initial temperature of water $= t_1 = 10°C$

$T_1 = 10 + 273 = 283$ K

Final temperature of water $= t_2 = 65$ °C

$T_2 = 65 + 273 = 338\ K$

$\Delta T = T_2 - T_1 = 338 - 283 = 55\ K$

Required: Amount of heat absorbed by the body $= \Delta Q = ?$

Formula: $\Delta Q = mc\Delta T$

Solution: By putting the values, the amount of heat absorbed can be foud out;

$\Delta Q = (0.5kg)(4200)(338 - 273)$

$\Delta Q = (0.5)(4200)(55)$

$\Delta Q = (2100)(55)$

$\boxed{\Delta Q = 115{,}500\ J}$

Answer: The required heat to increase the temperature is 115,500J.

8.6 An electric heater supplies heat at the rate of 1000 joule per second. How much time is required to raise the temperature of 200 g of water from 20°C to 90°C.

Data: Electric heater supplies heat at the rate $= \frac{\Delta Q}{t} = 1000 Js^{-1}$

Mass of the water $= m = 200g = 0.2kg$

Initial temperature $= t_1 = 20°C$

$T_1 = 20+273 = 293\ K$

Final temperature $= t_2 = 90°C$

$T_2 = 90+273 = 363\ K$

$\Delta T = T_2 - T_1$

$= 363 - 293 = 70\ K$

Required: How much time is required to raise the given temperature $= t = ?$

Solution: As we know that

$\Delta Q = mc\Delta T$

dividing both side by 't' to obtain rate of change of heat

$$\frac{\Delta Q}{t} = \frac{mc\Delta T}{t} \quad \text{------ (1)}$$

By putting the values in eq (1), we get;

$$\frac{\Delta Q}{t} = \frac{(0.2)(4200)(70)}{t}$$

$$1000 = \frac{(0.2)(4200)(70)}{t}$$

$$t = \frac{(0.2)(4200)(70)}{1000}$$

$\boxed{t = 58.8\ sec}$

Answer: Hence the time required to raise the required temperature $= t = 58.8$ sec

8.7 How much ice will melt by 50,000 J of heat? Latent heat of fusion of ice=336000 **Jkg^{-1}**

Data: Amount of heat = ΔQ_f = 5000 J

Latent heat of fusion of ice = H_f = 336000 Jkg^{-1}

Required: Mass of ice = m = ?

Formula: $\frac{\Delta Q_f}{H_f} = m$

Solution: By putting the values in given formula, value of mass can be found out:

$$\frac{50\cancel{000}}{336\cancel{000}} = m$$

$$m = \frac{50}{336}$$

$$m = 0.1488 kg$$

$$m = 0.1488 \times 10^3 g$$

$$m = 0.1488 \times 1000 g$$

$$m = 148.8 g$$

$$m = 149 g$$

$$\boxed{m = 149 g}$$

Answer: The required mass of the ice is 149 g.

8.8 Find the quantity of heat needed to melt 100g of ice at –10°C into water at 10°C.

Note:(Specific heat of ice is 2100 **$Jkg^{-1}K^{-1}$**, ***specific heat of water is 4200*** **$Jkg^{-1}K^{-1}$**, ***Latent heat of fusion of ice is 336000*** **Jkg^{-1}*)*.**

Data: Mass of ice to be melt = m = 100g = 0.1kg

Initial temperature = t_1 = –10°C

T_1 = –10+273 = 263 K

Final temperature = t_2 = 10°C

T_2 = 10+273 = 283 K

Specific heat of ice = c_1 = 2100 $Jkg^{-1}K^{-1}$

Specific heat of water = c_2 = 4200 $Jkg^{-1}K^{-1}$

Required: Find the quantity of heat needed to melt 100g of ice at –10°C into water at 10°C = Q = ?

Formula: The basic relation of specific heat capacity is used here that is $\Delta Q = mc\Delta T$

Solution: There are two steps to obtain total heat required to melt ice into water at required temperature.

Step I: First of all

Heat is required to bring the temperature of ice from -10°C to 0°C.

For this by using the relation $\Delta Q_1 = mc_i \Delta T$ ($\because c = c_i$)

By putting values in this equation, we get

$\Delta Q_1 = (0.1) \times (2100) \times (0°C - (-10°C)$

$\Delta Q_1 = (210)(10)$

$\boxed{\Delta Q_1 = 2100\ J}$

Step II: Amount of heat required to convert 0°C ice into 0°C water:

$\Delta Q_f = m \times H_f$

$= 0.1 \times 336000$

$\Delta Q_f = 33600\ J$

Step III: Now heat is required to convert this ice at 0°C to water at 10°C

So, again by using the above relation

$\Delta Q_2 = mc_w \ \Delta T$

By putting values in above equation, we get:

$\Delta Q_2 = (0.1)(4200)(10° - 0°)$

$\Delta Q_2 = 420(10)$

$\boxed{\Delta Q_2 = 4200\ J}$

Now obtain total heat to convert ice from -10°C to 10°C water, we should add these quantities of heat

$$\Delta Q = \Delta Q_1 + \Delta Q_f + \Delta Q_2$$

$$= 2100 + 33600 + 4200$$

$$\Delta Q = 39900\ J$$

Which is the required heat.

Answer: Hence to melt 100g of ice at –10°C into water at 10°C, 39900 J of heat is required.

8.9 How much heat is required to change 100 g of water at 100°C into steam? (Latent heat of vaporization of water is $2.26 \times 10^6\ Jkg^{-1}$).

Ans: Mass of water = 100g = m = 0.1 kg

Temperature of water = t = 100°C

Latent heat of vaporization of water = $\Delta H_v = 2.26 \times 10^6\ Jkg^{-1}$

Required: How much heat is required to undergo this change = Q = ?

Formula: As we know the formula of latent heat of vaporization = $\Delta Q_v = mH_v$

Solution: By using the above given formula, we get $\Delta Q_v = mH_v$

By putting values in above equation, we get:

$\Delta Q_v = (0.1)(2.26\times10^6)$

$\Delta Q_v = 226000$

$\Delta Q_v = 2.26\times10^5 J$

Answer: Hence;

The heat required to change 100g of water at 100°C into steam is $2.26\times10^5 J$.

8.10 Find the temperature of water after passing 5 g of steam at 100°C through 500 g of water at 10°C.

Note:(Specific heat of water is 4200 $Jkg^{-1}K^{-1}$, Latent heat of vaporization of water is $2.26\times10^6 Jkg^{-1}$).

Ans: Given: mass of water $= m_1 = 500g = 0.5kg$

Temperature of water $= T_1 = 10°C$

Mass of steam $= m_2 = 5g = 0.005kg$

Temperature of steam $= T_2 = 100°C$

$H_v = 2.26 \times 10^6 J kg^{-1}$

Required: $= T = ?$

Solution:

(i) Amount of heat required to change 0.005 kg of steam into 100°C of water:

i.e. $\Delta Q_1 = m_2 H_v = 0.005 \times 2.26 \times 10^6$

$\Delta Q_1 = 11300 J$

(ii) Amount of heat released from 0.005 kg water:

$\Delta Q_2 = m_2 c\Delta T$

$= 0.005 \times 4200 \times (100 - T)$

$= 21(100 - T)$

$\Delta Q_2 = 2100 - 21T$

(iii) Amount of heat absorbed by 0.5 kg of water:

$\Delta Q_3 = m_1 c\Delta T$

$= 0.5 \times 4200 \times (T - 10)$

$\Delta Q_3 = 2100 T - 21000$

Now

Absorbed heat = Released heat

$2100 T - 21000 = 11300 + 2100 - 21 T$

$2121 T = 34400$

$T = 16.21 °C$

Hence the final temperature of mixture is 16.21 °C.

OBJECTIVE TYPE QUESTIONS (MCQ'S+SHORT ANSWER) FROM PREVIOUS ANNUAL PAPERS OF ALL SECONDARY BOARDS (LAHORE, GUJRANWALA, FAISALABAD, MULTAN, SAHIWAL, SARGODHA, RAWALPINDI, D.G. KHAN And BAHAWALPUR)

8.1+8.2 Temperature and Heat+Thermometer

8.3+8.4 Specific Heat Capacity+Change of State

☆ **Tick the correct answer.**

1. **Degree of hotness or coldness of the body is called:** (DGK. GI)
   (A) Heat (B) Thermal conductivity (C) Heat capacity (D) Temperature
2. **Which of the materials has large value of specific heat:** (LHR. GI. SGD. GII. GRW. GII. MLN. GII. SGD. GII)
   (A) Copper (B) Ice (C) Water (D) Mercury
3. **Which material has large value of temperature coefficient of linear expansion?** (FBD. GII)
   (A) Gold (B) Brass (C) Aluminium (D) Steel
4. **Temperature of Ice in Freezer is:** (MLN. GI)
   (A) 0°C (B) -8°C (C) -18°C (D) -28°C
5. **The temperature 50°C on celsius scale is equal to fahrenheit scale:** (MLN. GII)
   (A) 112°F (B) 120°F (C) 122°F (D) 123°F
6. **Normal human body temperature is:** (SWL. GI. DGK. GI & GII. FBD. GII. SGD. G I. BWP. GII)
   (A) 15°C (B) 37°C (C) 37°F (D) 98.6°C
7. **On kelvin scale the value of absoulte zero is:** (SGD. GI. RWP. GI. FBD. GI. RWP. GII)
   (A) 100°C (B) 373 K (C) –273°C (D) 273 K
8. **Murcury is used as Thermometric Material because it has:** (BWP. GI)
   (A) Uniform Thermal Expansion (B) Low Freezing Point
   (C) Small Heat Capacity (D) All the given properties
9. **The boiling point of water is:** (MLN. GI)
   (A) 98°C (B) 78°C (C) 100°C (D) 90°C
10. **On Celsius scale, the temperature 300K will be:** (RWP. GI)
    (A) 26C° (B) 25C° (C) 24C° (D) 27C°
11. **Water freezes at:** (LHR. GII. GRW. GI. SWL. GII)
    (A) 0° F (B) 32° F (C) –273 K (D) 0 K
12. **The value of specific heat of silver in joules per kilogram per kelvin is:** (RWP. GI)
    (A) 138.6 (B) 128.0 (C) 235.0 (D) 134.8

13. The specific heat of Iron in Joules per Kilogram per Kelvin is:

(BWP. G II, 2014) (GRW. G I, 2015)

(A) 378 (B) 920 (C) 470 (D) 903

Answers

1.	Temperature	**2.**	Water	**3.**	Aluminium	**4.**	-18°C		
5.	122°F	**6.**	37°C	**7.**	-273°C	**8.**	All the given properties		
9.	100°C	**10.**	27C°	**11.**	32° F	**12.**	235.0	**13.**	470

☆ **Give short answer to the following questions.**

1. Define internal energy. (LHR. GI, FBD. GII, SWL. GI, SGD. GI, DGK. GII, BWP. GI)

Ans. Internal Energy: The sum of kinetic energy and potential energy associated with the atoms, molecules and particles of a body is called its internal energy.

2. Define heat and temperature.

(LHR. GI, MLN. GI, & GII, SWL. GII, RWP. GI & GII, DGK. GI, & GII, BWP. GII)

Ans. Heat: Heat is the energy that is transferred from one body to the other in thermal contact with each other as a result of the difference of temperature between them.

Temperature: Temperature of a body is the degree of hotness or coldness of the body.

3. What are the factors on which internal energy depends? (FBD. GI, SGD. GII)

Ans. Internal energy depends upon the following factors.

1. Mass of a body.
2. K.E. of molecules of a body.
3. P.E. of molecules of a body

4. Why does heat flow from hot body to cold body? (MLN. GII, SGD. GI, DGK. GI & G II)

Ans. Heat flows from hot body to cold body to attain the condition of thermal equilibrium.

5. Differentiate between heat and internal energy. (RWP. GII, SWL. GII)

Ans. Heat: Heat is the energy that is transferred from one body to the other in thermal contact with each other as a result of the difference of temperature between them.

Internal energy: The sum of kinetic energy and potential energy associated with the atoms, molecules and particles of a body is called its internal energy.

6. How does heating affect the motion of molecules of a gas? (BWP. GII, LHR. GII)

Ans. By heating the gas, its molecules get high kinetic energy and start to collide more randomly. And motion of gas molecules is increased by heating. So pressure of gas molecules increase by heating.

7. What will be temperature on Kelvin scale of temperature when it is 20°C on Celsius scale? (LHR. GI, RWP. GI)

Sol. $C = 20°C$

as $T = 273 + C$

T = 273 + 20 = 293K

8. Convert 100°F into the temperature on Celsius scale. (LHR GII, SGD. GI, DGK. GI & GII)

Sol. F = 100°F

Since 1.8C = F - 32

∴ 1.8C = 100 - 32

or 1.8C = 68

or C = 68/1.8

or C = 37.8°C

Thus 100°F is equal to 37.8°C.

9. Write two scales of temperature. (GRW. GI & GII, SWL. GI, MLN. G II)

Ans. 1. Celsius Scale

2. Fahrenheit scale

10. Define thermometer. (GRW. GI, SWL. GI, DGK. GI)

Ans. Thermometer: A thermometer is a device which is used to measure the temperature of a body.

11. Change 300 K on Kelvin into Celsius scale. (GRW. GII, MLN. GI & GII, LHR. GII)

Sol. T = 300K

Since C = T(K) - 273

∴ C = (300 - 273)°C

or C = 27°C

12. Convert 50° C on celsius scale into Fahrenheit temperature scale. (FBD. GI)

Ans. C = 50°C

Since F = (1.8 × C + 32)

F = (1.8 × 50 + 32)

or F = 122°F

Thus, 50°C on Celsius scale is 122°F on Fahrenheit scale.

13. How can Celsius scale be converted into Kelvin and Fahrenheit scales? (SWL. GII, RWP. GII)

Ans. Conversion of temperature from Celsius scale to Kelvin scale: The temperature T on Kelvin scale can be obtained by adding 273 in the temperature C on Celsius scale, thus;

$$T(k) = 273 + C$$

Conversion of temperature from Celsius to Fahrenheit scale:

Since 100 divisions on Celsius scale are equal to 180 divisions on Fahrenheit scale. Therefore, each division on Celsius scale is equal to 1.8 divisions on Fahrenheit scale.

Moreover, 0°C corresponds to 32°F.

$F = 1.8\,C + 32$

14. What is thermometer? Why mercury is preferred as a thermometric material? (SWL. GII, DGK. GI)

Ans. Thermometer: A thermometer is a device which is used to measure the temperature of a body.

Mercury is preferred as a thermometric substance due to following properties.

- It is easily visible.
- It has uniform thermal expansion.
- It has low freezing point and high boiling point.
- It has a small specific heat capacity.

15. Convert 60°C on celsius scale into Fahrenheit scale. (BWP. GII)

Ans. $C = 60°$

Since $F = 1.8C + 32$

$= 1.8\,(60) + 32$

$= 108 + 32$

$F = 140°F$

16. What is meant by upper and lower fixed points of thermometer? (LHR. GI, SWL. GI, BWP. GII)

Ans. Lower fixed point: The lower fixed point is marked to show the position of liquid in the thermometer when it is placed in ice.

Upper fixed point: Upper fixed point is marked to show the position of liquid in the thermometer when it is placed in steam at standard pressure above boiling water.

17. Define temperature and thermometer. (GRW. GII)

Ans. Temperature: Temperature of a body is the degree of hotness or coldness of the body.

Thermometer: A device that is used to measure the temperature of a body is called thermometer.

18. Write two properties of a thermometric liquid. (GRW. GII)

Ans. Properties of thermometric liquid:

A thermometric liquid should have the following properties.

1. It should be visible. 2. It should have uniform thermal expansion.
3. It should have a low freezing point.

19. Write the equation of conversion from Kelvin scale to Celsius scale. (SWL. GI)

Ans. Conversion of temperature from Kelvin to Celsius scale:

The temperature on Celsius scale can be found by subtracting 273 from the temperature in Kelvin Scale. Thus,

$$C = T(K) - 273$$

20. Define Fahrenheit scale and Kalvin scale. (SGD. GI)

Ans. Fahrenheit scale (°F): On Fahrenheit scale, the interval between lower and upper fixed points is divided into 180 equal parts.

Kelvin scale: On Kelvin scale, the interval between the lower and upper fixed points is divided into 100 equal parts.

21. Describe the use and range of a clinical thermometer. (SGD. GII)

Ans. A clinical thermometer is used to measure the temperature of human body. It has a narrow range from 35°C to 42°C. It has a construction that prevents the mercury to return. Thus, its reading does not change until reset.

22. Write two characteristics of the Liquid used in Thermometer. (BWP. GII)

Ans.
- Mercury freezes at -39°C and boils at 357°C.
- Mercury has all thermometric properties, which are necessary for thermometric material.

23. Convert 20°C on Celsius scale to Kelvin scale temperature. (FBD. GII, SGD. GII,)

Sol. $C = 20°C$

as $T = 273 + C$

$T = 273 + 20 = 293K$

24. Define specific heat. (LHR. GI, GRW. GI, MLN. GI, SWL. GI & GII, BWP. GI, SGD. GI, DGK. GI, & GII)

Ans. Specific Heat: The specific heat of a substance is the amount of heat required to raise the temperature of 1kg mass of that substance through 1K.

Formula: Specific heat of any substance can be found out by using following formula:

$$c = \frac{\Delta Q}{m\Delta T}$$

25. How specific heat differs from heat capacity? (FBD. GI)

Ans. Specific heat: The specific heat of a substance is the amount of heat required to raise the temperature of 1kg mass of that substance through 1k.

Heat Capacity: Heat capacity of a body is the quantity of thermal energy absorbed by it for one kelvin (1K) increase in its temperature.

26. Why water is used in cooling system of vehicles? (FBD. GII)

Ans. The cooling system of automobiles uses water to carry away unwanted thermal energy. In an automobile, large amount of heat is produced by its engine due to which its temperature goes on increasing. The engine would cease unless it is not cooled down.

27. What is meant by Heat Capacity and write its formula?

(MLN. GII, GRW. GII, SWL. GI, SGD. GII)

Ans. Heat Capacity: Heat capacity of a body is the quantity of thermal energy absorbed

by it for one kelvin (1K) increase in its temperature.

Formula: Heat capacity = mc

28. How much heat is required to increase the temperature of 0.5 kg of water from 10°C to 65°C? (SWL. GII, RWP. GII)

Ans. Mass $= m = 0.5$ kg

Increase in temperature $= T_2 = 65°C$

$= 65+273 = 338$ K

Original temperature $= T_1 = 10°C$

$= T_1 = 10+273 = 283$ K

Specific heat of water $= c = 4200\ Jkg^{-1}K^{-1}$

Required: Amount of heat absorbed by the body

$= \Delta Q = ?$

Formula: $\Delta Q = mc\Delta T$

Sol: By putting the values, the amount of heat absorbed can be foud out;

$\Delta Q = (0.5kg)(4200\ Jkg^{-1}K^{-1})(T_2 - T_1)$

$\Delta Q = (0.5kg)(4200)(338 - 273)$

$\Delta Q = (0.5)(4200)(55)$

$\Delta Q = (2100)(55)$

$\boxed{\Delta Q = 115,500\ J}$

Ans. The required heat to increase the temperature is 115,500J.

29. Describe relation between Heat Capacity and Quantity of substance. (BWP. GI)

Ans. Relation between heat capacity and quantity of substance:

Mass and heat capacity are directly proportional to each other larger is the quantity of a substance, higher will be its heat.

8.5+8.6	Latent heat of fusion + Latent heat of vaporization
8.7+8.8	The Evaporation + Thermal Expansion

☆ **Tick the correct answer.**

1. **Which of the following affects evaporation?** (SWL. GI, FBD. GI, DGK. GI & GII, LHR. GII)
   (A) temperature (B) surface area of liquid (C) wind (D) all of these
2. **The specific heat of water is:** (GRW. GII)
   (A) $800\ Jkg^{-1}K^{-1}$ (B) $4200\ Jkg^{-1}K^{-1}$ (C) $2500\ Jkg^{-1}K^{-1}$ (D) $1760\ Jkg^{-1}K^{-1}$
3. **The co-efficient of linear expansion and volume expansion are related by the equation:** (LHR. GI)
   (A) $\beta = \alpha$ (B) $\beta = 3\alpha$ (C) $\beta = 2\alpha$ (D) $\beta = \frac{\alpha}{2}$

Answers

1. all of these 2. 4200 $Jkg^{-1}K^{-1}$ 3. $\beta = 3\alpha$

☆ **Give short answer to the following questions.**

1. Define latent heat of fusion and write its value for ice.

(FBD. GII, MLN. GI & GII, RWP. GII, DGK. GI & GII, BWP. GII, SWL. GI & GII)

Ans. Latent heat of fusion: Heat energy required to change unit mass of a substance from solid to liquid state at its melting point without change in its temperature is called its latent heat of fusion denoted by H.

Latent heat of fusion of ice is $3.36\times10^5 Jkg^{-1}$

2. What is meant by latent heat of fusion? (BWP. GII, GRW. GI)

Ans. Latent heat of fusion: Heat energy required to change unit mass of a substance from solid to liquid state at its melting point without change in its temperature is called its latent heat of fusion denoted by H.

3. How many types are of Latent Heat? Write its names. (LHR. GII)

Ans. There are two types of laten heat:

1. Latent heat of fusion. 2. Latent heat of vaporization.

4. Define and write down the mathematical form of latent heat of fusion. (RWP. GI)

Ans. Latent heat of fusion: Heat energy required to change unit mass of a substance from solid to liquid state at its melting point without change in its temperature is called its latent heat of fusion denoted by H_f.

Mathematical form:

$$\Delta Q_f = mH_f$$

5. Define latent heat of vaporization. (GRW. GII, FBD. GI & GII, MLN. GII, SGD. GII)

Ans. Latent Heat of Vaporization: The quantity of heat that changes unit mass of a liquid completely into gas at its boiling point without any change in its temperature is called its latent heat of vaporization denoted by H_v.

$$H_v = \frac{\Delta Q_v}{m}$$

6. Define co-efficient of linear thermal expansion and write its formula.

Ans. Co-efficient of linear thermal expansion: (GRW. GII, MLN. GI & GII, BWP. GI & GII)

Co-efficient of linear thermal expansion $\propto$ of a substance can be defined as fractional increase in its length per kelvin rise in temperature.

Formula: $\propto = \frac{\Delta L}{L_0 \Delta T}$

7. What is difference between evaporation and vaporization? (FBD. GII, RWP. GI)

Ans. Evaporation: Evaporation is the changing of a liquid into vapours (gaseous state)

from the surface of the liquid without heating it.

Vaporization: Vaporization is the changing of a liquid into vapours (gaseous state) from the surface of liquid with heating it.

8. Give the name of factors on which Evaporation of a liquid depends. (SGD. GII, FBD. GII, BWP. GI)

Ans. Evaporation of liquid depends upon the following factors:

1. Temperature
2. Surface Area
3. Wind
4. Nature of liquid

9. Give two uses of cooling effects by evaporation. (RWP. GI)

Ans. i. Evaporation of perspiration helps to cool our bodies.

ii. Cooling is produced in refrigerators by evaporation of liquefied gas. which produce cooling effects.

10. Does nature of Liquid effect Evaporation? Give an example. (BWP. GI, GRW. GI)

Ans. Liquids differ in the rate at which they evaporate.

Example: Put a few drops of ether or spirit on the palm, it evaporates rapidly while for drops of water on the palm does not evaporate rapidly.

11. What is the effect of temperature on evaporation? (LHR. GII, RWP. GII)

Ans. Effect of temperature on evaporation:

Evaporation takes place at all temperature from the surface of a liquid.

Evaporation is faster at high temperature, more molecules of a liquid are moving with high velocities. Thus, more molecules are escaping from its surface.

12. Why wet clothes dry up more quickly in summer than in winter? Also define this process. (MLN. GI)

Ans. Evaporation is faster at high temperature than at low temperature thus, is summer, at higher temperature, more molecules of a liquid are moving with high velocities and wet clothes dry up more quickly in summer then in winter.

13. Does Water and Spirit evaporate at the same rate? Explain. (MLN. GI)

Ans. Liquids differ in the rate at which they evaporate. If we put a few drops of ether or spirit on the palm, it evaporates rapidly while few drops of water on the palm does not evaporate rapidly.

14. Give two uses of cooling effect by evaporation. (SGD. GI)

Ans. Uses of cooling effect by evaporation:

1. Evaporation of perspiration helps to cool our bodies.
2. Cooling is produced in refrigerators by evaporation of liquefied gas. This produces cooling effect.

15. What is meant by Evaporation? (BWP. GI)

Ans. Evaporation: Evaporation is the changing of a liquid into vapours (gaseous state) from the surface of the liquid without heating it.

16. Define the coefficient of linear expansion. (LHR. GII, GRW. GII, FBD. GI)

Ans. Coefficient of Linear Expansion:

Co-efficient of linear expansion α of a substance can be defined as fractional increase in its length per Kelvin rise in temperature.

17. What do you mean by anomalous expansion of water? (FBD. GI)

Ans. Water on cooling below 4°C begins to expand until it reaches 0°C. On further cooling its volume increases suddenly as it changes into ice at 0°C. When ice is cooled below 0°C, it contracts i.e. its volume decreases like solids. This unusual expansion of water is called the anomalous expansion of water.

18. Write down two uses of thermal expansion in daily life. (SGD. GII, FBD. GII)

Ans. i. For the measurement of temperature: In thermometers, thermal expansion is used in temperature measurements.

ii. Opening the metallic cap of bottle:

To open the cap of a bottle that is tight enough, immerse it in hot water for a minute or so. Metal cap expands and becomes loose. It would now be easy to turn it to open.

19. Write down the values of co-efficients of linear thermal expansion of gold and silver. (RWP. GI)

Ans. Gold: $\alpha = 1.3 \times 10^{-5} k^{-1}$ **Silver:** $\alpha = 1.93 \times 10^{-5} k^{-1}$

20. Describe the use of Bimetal Strip. (BWP. GI, LHR. GI)

Ans. Uses of bimetal strips:

Bimetal strips are used for various purposes.

- Bimetal strips are used in thermometers to measure temperatures especially in furnaces and ovens.
- Bimetal strips are also used in thermostats. Bimetal thermostat switch is used to control the temperature of heater coil in an electric iron as shown in given figure.

21. What is meant by thermal equilibrium? (LHR. GI)

Ans. Thermal equilibrium: When two bodies of different temperatures are brought close to each other, the heat is released by hot body and is absorbed by cold body. So thermal equilibrium is the condition in which two bodies attain same temperature.

22. What is meant by thermal expansion? (GRW. GI, RWP. GII)

Ans. Thermal expansion: Expansion due to heating is called thermal expansion.

23. Define co-efficient of volume thermal expansion. (FBD. GI)

Ans. Co-efficient of volume thermal expansion: The co-efficient of volume thermal expansion β can be defined as the fractional change in its volume per kelvin change in temperature.

24. What is meant by volume thermal expansion? Write its equation. (FBD. GI)

Ans. Volume thermal expansion: The volume of solid changes with the change in temperature and is called volume thermal expansion or cubical thermal expansion.

Equation: $V = V_0 (1 + \beta \Delta T)$

25. Write the names of types of Thermal Volume expansion for liquids. (MLN. GI)

Ans. Types of thermal volume expansion for liquids: When a liquid is heated, both liquid and the container undergo a change in their volume. So there are two types of thermal volume expansion for liquid.

- Apparent volume expansion
- Real volume expansion.

26. Why liquids expand on heating? (SWL. GII)

Ans. Process of liquid expansion:

The molecules of liquids are free to move in all directions within the liquid. On heating a liquid, the average amplitude of vibration of its molecules increases. The molecules push each other and need more space to occupy. This accounts for the expansion of the liquid when heated.

27. Define consequences of thermal Expansion and write its example. (SGD. GI)

Ans. The expansion of solids may damage the bridges, railway tracks and roads as they are constantly subjected to temperature changes. So provision is made during construction for expansion and contraction with temperature.

Expansion of railway track:

Railway tracks buckled on a hot summer day due to expansion if gaps are not left between section.

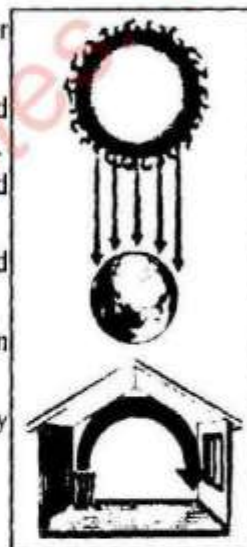
28. Why gaps are left in railway tracks? Explain it. (SGD. GII)

Ans. Gaps are left in railway tracks to compensate thermal expansion during hot season.

TRANSFER OF HEAT

STUDENTS LEARNING OUTCOMES

After studying this unit, the students will be able to:

- recall that thermal energy is transferred from a region of higher temperature to a region of lower temperature.
- describe in terms of molecules and electrons, how heat transfer occurs in solids.
- state the factors afffecting the transfer of heat throuh solid conductors and hence, define the term "Thermal Conductivity".
- solve problems based on thermal conductivity of solid conductors.
- write examples of good and bad conductors of heat and describe their uses.
- explain the convection currents in fluids due to difference in density.
- state some examples of heat transfer by convection in everday life.
- explain insulation reduces energy transfer by conduction.
- describe the process of radiation from all objects.
- explain that energy transfer of a body by radiation does not require a material medium and rate of energy transfer is affected by:
  - Colour and texture of the surface
  - Surface temperature
  - Surface area

Conceptual Linkage
This unit is built on
Modes of heat transfer —Science—VII
This unit leads to:
Thermodynamics —Physics—XI

INVESTIGATION SKILLS:

- Describe convection in water heating by putting a few pinky crystals in a round bottom flask.
- Explain that water is a poor conductor of heat.
- Investigate the absorption of radiation by a black surface and silvery surfaces using Leslie cube.
- Investigate the emission of radiation by a black surface and silvery surfaces using Leslie cube.

SCIENCE, TECHNOLOGY AND SOCIETY CONNECTION:

- describe the use of cooking utensils, electric kettle, air conditioner, refrigerator cavity wall insulation, vacuum flask and household hot-water system as a

consequence of heat transmission processes.

- explain convection in seawater to support marine life.
- describe the role of land breeze and sea breeze for moderate costal climate.
- describe the role of convection in space heating.
- Identify and explain some of the everyday applications and consequences of heat transfer by conduction. convection and radiation.
- explain how the birds are able to fly for hours without flapping their wings and glider is able to rise by riding on thermal currents which are streams of hot air rising in the sky.
- explain the consequence of heat radiation in greenhouse effect and its effect in global warming.

Major Concepts:

9.1 The three process of heat transfer
9.2 Conduction
9.3 Convection
9.4 Radiation
9.5 Consequences and everday applications of heat transfer

Introduction: Heat is an important form of energy. It is necessary for our survival. We need it to cook our food and to maintain our body temperature. Heat is also needed in various industrial processes. How to protect ourselves from high as well as low temperature, needs knowledge of how heat travels. In this unit, we will study various ways of heat transfer.

9.1 Transfer of Heat

Q.1. What is heat? How heat is transfered? Explain briefly?

Ans: Heat: Heat is an important form of energy which is transferred from one body to other due to the difference in temperature.

Transfer of heat: When two bodies at different temperature are in thermal contact with each other. Thermal energy from a hot body flows to the cold body in the form of heat. This is called as transfer of the heat.

Natural process:

Transfer of heat is a natural process.

Direction of transfer of heat: Transfer of heat continues all the time as long as the bodies in thermal contact are at different temperature.

Ways of heat transfer:

There are three ways by which transfer of heat takes place.

1. Conduction 2. Convection 3. Radiation

Explanation with diagram:

Three ways of transfer of heat can be shown or expressed diagrammatically as.

Figure 9.1: Three ways of heat transfer

Quick Quiz:

Think of objects around us getting heat or giving out heat.

(1) Ice cube placed, at a room temperature melts soon because it gets heat from the surroundings.

(2) A hot piece of iron, placed at room temperature, cools slowly because it gives out its heat to environment.

(3) A black and rough surface absorbs more heat than a white or polished surface. Therefore the bottoms of cooking pots are made black to increase the absorption of heat from fire.

(4) The glass of greenhouse get heat.

9.2 Conduction

Q.2. What is the process of conduction? Explain it briefly.

Ans: Conduction: The mode of transfer of heat by vibrating atoms and free electrons in solids from hot to cold parts of a body is called conduction of heat.

Conduction of heat: Both metals and non-metals conduct heat, but behave differently regarding the transfer of heat.

Metals are generally better conductors than non-metals.

Metals are good conductors: The substances through which heat does conduct are called good conductors. All metals are good conductors of heat.

Example: The handle of metal spoon held in hot water soon gets warm.

Figure 9.2: (b) In solids heat is transferred from one part to the others by conduction

Non metals are bad conductors:

The substances through which heat does not conduct, are called bad conductors or insulators.

Examples: The handle of wood spoon held in hot water does not get warm.

Wood, cork, cotton, wool, glass, rubber etc are bad conductors or insulators.

Explanation of conduction process:

Consider a metal rod as shown in given figure.

One end of it is heated by a burner or candle. The other end soon becomes hot due to transfer of heat from hot end to the cold end. The atoms or molecules present at the end which is heated by a burner, begin to vibrate more

rapidly. They also collide with their neighbouring atoms or molecules. In doing so, they pass some of their energy to neighbouring atoms or molecules during collisions with them with the increase in their vibrations. These atoms or molecules in turn pass on a part of the energy to the neighbouring particles. In this way some heat reaches the other parts of the solids. This is a slow process and very small transfer of heat takes place from hot to cold parts in solids.

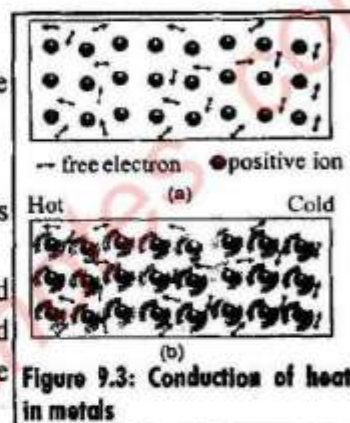
Free electrons:

Metals have free electrons which can move from one place to another, by getting energy.

Figure 9.3: Conduction of heat in metals

Transfer of electrons from hot to cold end of a rod:

Free electrons in metals move with very high velocities within the metal objects.

They carry energy at a very fast rate from hot to cold parts of the object as they move. Thus, heat reaches the cold parts of the metal objects from its hot part much more quickly than non-metals.

DO YOU KNOW?

Why Styrofoam boxes are used to keep food hot or ice cream cold for a long time? Styrofoam is a bad conductor of heat. It does not allow heat to leave or enter the box easily.

Q.3. What is thermal conductivity? Give its explanation. On which factor thermal conductivity depends? Prove its formula.

Ans: Thermal conductivity: Thermal conductivity of a substance can be defined as;

The rate of flow of heat across the opposite faces of a metre cube of a substance maintained at a temperature difference of one kelvin.

Conduction of heat:

Conduction of heat occurs at different rates in different materials. In metals, heat flows rapidly as compared to insulators such as wood or rubber.

Figure 9.4: Rate at which heat conducts through different solids depends upon various factors.

Explanation:

Consider a solid block as shown in given figure.

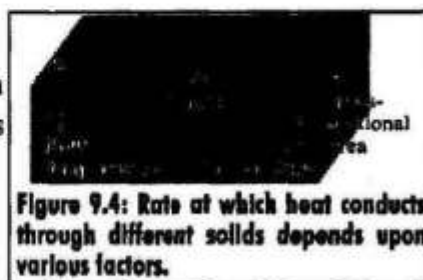
One of its two opposite faces each of cross-sectional area A is heated to a temperature T_1.

Heat Q flows along its length L to opposite face at temperature (T_2) in t seconds.

Rate of flow of heat:

The amount of heat that flows in unit time is called the rate of flow of heat.

Formula to find the rate of flow:

Rate of flow of heat can be found out by the given formula.

Rate of flow of heat $= \frac{Q}{t}$

Factors on which thermal conductivity depends:

Thermal conductivity or rate at which heat flows depends upon following factors.

- **(i)** Cross sectional area of the solid (A)
- **(ii)** Length of the solid (L).
- **(iii)** Temperature difference between the hot and cold ends $(T_1 - T_2)$.
- **(iv)** Nature of the material of solid

Cross-sectional area of the solid:

Larger cross-sectional area A of a solid contains larger number of molecules and free electrons on each layer parallel to its cross-sectional area and hence greater will be the rate of flow of heat through the solid. Thus rate of flow of heat is given as:

$$\text{Rate of flow of heat } \frac{Q}{t} \propto A \quad \text{.......... (1)}$$

Length of the solid:

Larger is the length between the hot and cold ends of the solid, more time it will take to conduct heat to the colder end and smaller will be the rate of flow of heat. Thus

$$\text{Rate of flow of heat } \frac{Q}{t} \propto \frac{1}{L} \quad \text{.......... (2)}$$

Temperature difference between ends:

Greater is the temperature difference $T_1 - T_2$ between hot and cold faces of the solid, greater will be the rate of flow of heat. Thus rate of heat flow

$$\frac{Q}{t} \propto (T_1 - T_2) \quad \text{.......... (3)}$$

Now by combining eq # 1 & 2 and 3 we get:

$$\frac{Q}{t} \propto \frac{A(T_1 - T_2)}{L}$$

By changing the sign of proportionality into equality, a constant (k) is used.

So, Rate of flow of heat $$\frac{Q}{t} = k\frac{A(T_1 - T_2)}{L} \quad \text{.......... (4)}$$

Here k is the proportionality constant called thermal conductivity of the solid.

Value of k:

Value of k depends on the nature of the substance and is different for different material.

From equation # 4 the value of k can be found out as;

$$k = \frac{Q}{t} \times \frac{L}{A(T_1 - T_2)}$$

Thermal conductivities of some substances:

Thermal conductivities of some common substances are given in the table.

Substance	$Wm^{-1}K^{-1}$	Substance	$Wm^{-1}K^{-1}$
Air (dry)	0.026	Iron	85
Aluminium	245	Lead	35
Brass	105	Plastic foam	0.03
Brick	0.6	Rubber	0.2
Copper	400	Silver	430
Glass	0.8	Water	0.59
Ice	1.7	Wood	0.08

Q.4. (a) In houses, what is the meaning of good thermal insulation? Which measures are taken to save energy?

(b) For what purposes conductors and non conductors are used? Write in detail.

Ans: (a) In houses, good thermal insulation means lower consumption of fuel.

Important measures to save energy:

In houses, following measures may be taken to save energy.

- Hot water tanks are insulated by plastic or foam lagging.
- Wall cavities are filled with plastic foam or mineral wool.
- Ceiling of rooms is covered by insulating materials (false ceiling).
- Double glazed window panes are used. These window panes have air between glass sheets that provides good insulation.

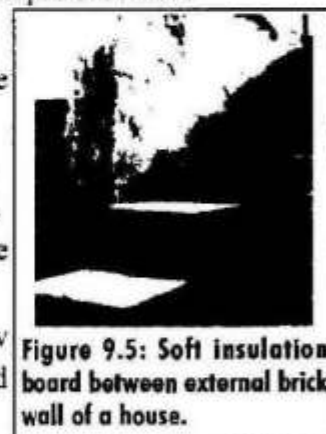



Figure 9.5: Soft insulation board between external brick wall of a house.

(b) Uses of conductors:

- Good conductors are used when quick transfer of heat is required through a body.
- Cookers, cooking plate, boiler, radiators and condensers of refrigerators, etc. are made of metals such as aluminium and copper for the better conduction.
- Metal boxes are used for making ice, ice cream, etc.
- Sauce pans are made of metal for quick heat transfer.

Do you know?

Sauce-pans are made of metal for quick heat transfer

Uses of non-conductors:

- Insulators or bad conductors are used in home utensils such as handles of sauce-pans, hot plates, spoons etc. They are made up of wood or plastic.
- Air is one of the bad conductors or best insulator. That is why cavity walls i.e two walls separated by an air space and double glazed windows keep the houses warm in winter and cool in summer.
- Some of the non-conductors are used for laggings to insulate water pipes, hot water cylinders, ovens, refrigerators, walls and roofs of houses.
- Woollen cloth is used to make warm winter clothes.
- Feathers give good thermal insulation especially when fluffed up.

For your Information

Water is a poor conductor. Water at the top in the test tube starts boiling after getting heat from the burner without melting ice.

Do you know?

Feathers give good thermal insulation especially when fluffed up.

Examples of non-conductors:

Wood and plastic are non conductors. Materials which trap air i.e. wool, felt, fur, feathers, polystyrenes, fibre glass are also bad conductors.

Example 9.1 ***The exterior brick wall of a house of thickness 25 cm has an area 20 m². The temperature inside the house is 15°C and outside is 35°C. Find the rate at which thermal energy will be conducted through the wall, the value of k for brick is 0.6 Wm⁻¹ K⁻¹.***

Solution:

$A = 20\ m^2$

$L = 25\ cm = 0.25\ m$

$T_1 = 35 + 273 = 308\ K$

$T_2 = 15 + 273 = 288K$

$\Delta T = T_1 - T_2$

$= 308\ K - 288\ K = 20\ K$

$k = 0.6\ Wm^{-1}\ K^{-1}$.

Using equation 9.2, rate of conduction of thermal energy is

$$= \frac{kA(T_1 - T_2)}{L}$$

$$= \frac{0.6\ Wm^{-1}K^{-1} \times 20\,m^2 \times 20\,K}{0.25\,m}$$

$$= 960 \text{ watt or } 960\ Js^{-1}$$

Thus, the rate of flow of thermal energy across the wall will be 960 joules per second.

9.3 Convection

Q.5. What is convection process? Describe it briefly.

Ans: Convection: Transfer of heat by actual movement of molecules from hot place to a cold place is known as convection.

Transfer of heat in liquids and gases:

Liquids and gases are poor conductors of heat. However, heat is transferred through **fluids** (liquids or gases) easily by the method of convection.

Explanation by an example:

Convection process can be explained by an example.

Suppose a part of a liquid or a gas is heated by a flame as shown in the given figure.

- A liquid or a gas becomes lighter (less dense) as it expands on heating. Hot liquid or gas rises up above the heated area.
- The cooler liquid or gas from the surroundings fills the place which in turns is heated up. In this way, all the fluid is heated up.

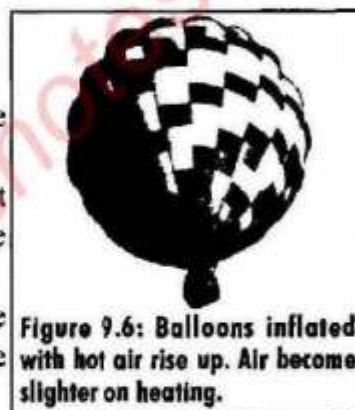



Figure 9.6: Balloons inflated with hot air rise up. Air become slighter on heating.

Actual movement of molecules in convection process:

It is observed and concluded that in convection process the transfer of heat through fluids takes place by the actual movement of heated molecules from hotter part to colder parts of the fluids.

Q.6. With the help of a simple experiment show that transfer of heat in liquids obeys the convection process.

Ans: To show that the transfer of heat in liquids is done only due to convection process, following experiment is performed.

Experiment: Steps of experiment are given as:

- Take a beaker and fill two-third of it with water.
- Heat the beaker by keeping a burner below it.
- Drop two or three crystals of potassium permanganate in the water.

Observations: It will be seen that coloured streaks of water formed by the crystals move upwards above the flame and then move downwards from side ways as shown in figure.

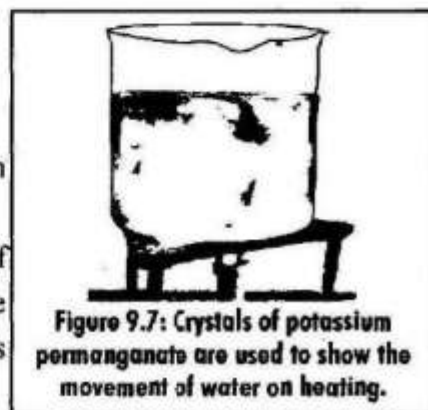



Figure 9.7: Crystals of potassium permanganate are used to show the movement of water on heating.

Conclusion: These coloured streaks shows that transfer of heat in the liquid is by the actual movement of molecules or convection process.

Mechanism of convection in the beaker:

When the water at the bottom of the beaker gets hot, it expands, becomes lighter and rises up. While the cold but denser water moves downward to take its place.

Q.7. What do you understand by convection currents in air? Write the use of convection currents in daily life.

Ans: Convection currents in air:

Gases also expand on heating, thus convection currents are easily set up due to the differences in the densities of air at various parts in the atmosphere.

Example: Convection currents of air can be observed by a simple experiment set up as shown in the given figure.

The emitting smoke is showing the path of the convection.

fig.9.8 Smoke showing the path of the convection

Uses of convection currents:

Convection currents occur on a large scale in nature. Some uses of convection currents are as;

- Convection currents set up by electric, gas or coal heaters help to warm our homes and offices.
- Central heating systems in buildings work on the same principle by convection.
- The day-to-day temperature changes in the atmosphere result from the circulation of warm or cold air that travels across the region.
- Land and sea breezes are also the examples of convection current.

Q.8. Write small note on followings.

(a) Land and sea breezes (b) Gliding

(a) Land and sea breezes:

Land and sea breezes are the result of convection.

Process of sea breeze:

On a hot day, the temperature of the land increases more quickly than the sea.

It is because the specific heat of land is much smaller as compared to water. The air above land gets hot and rises up. The cold air from the sea begins to move towards the land as shown in the given figure. It is called sea breeze.

Figure 9.9: Sea breeze blows from sea to land in day time.

Land breeze: At night, the land cools faster than the sea. Therefore, air above the sea is warmer, rises up and the colder air from the land begins to move towards the sea as shown in given figure. It is called land breeze.

Figure 9.10: Land breeze blows from land to sea during night

Importance of land and sea breeze:

Land and sea breezes help to keep the temperature moderate in coastal areas.

(b) Gliding: A glider looks like a small aeroplane without engine as shown in the figure.

Principle of glider: Glider pilots use upward movement of hot air currents due to convection of heat.

Thermals: The rising currents of hot air are called thermals.

Gliders ride over these thermals.

Figure 9.11: A glider

Importance of upward movement of air currents in thermals:

The upward movement of air currents in thermals help them to stay in air for a long period.

Process of gliding in birds:

The birds stretch out their wings and circle in thermals.

The upward movement of air helps birds to climb up with it.

Figure 9.12: Birds fly taking the advantage of thermal air currents

Examples of thermal climbers: Eagles, hawks and vultures are expert thermal climbers.

Importance of gliding in birds:

After getting a free lift, birds are able to fly for hours without flapping their wings. They glide from one thermal to another and thus travel through large distances and hardly need to flap their wings.

9.4 Radiation

Q.9. What is radiation process? Explain by giving examples:

Ans: Radiation: Radiation is the mode of transfer of heat from one place to another in the form of waves called electromagnetic waves.

Example # 1:

Solar energy reaches to Earth through radiation:

Our Sun is the major source of heat energy. It reaches us neither by conduction nor by convection, because the space between the Sun and the Earth's atmosphere is empty. There is a third mode called radiation by which heat travels from one place to another. It is through radiation that heat reaches us from the Sun.

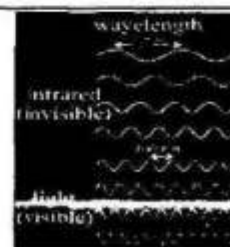



Figure 9.13: Thermal radiations and visible light spectrum.

Example # 2:

Another example of transfer of heat by radiation is the heat received from a fire place such as shown in the given figure.

Figure 9.14: Heat from the fireplace reaches us by radiation

Reason: Fireplace are used for room heating. Air is a poor conductor of heat. So heat does not reach us by conduction through air from a fireplace, nor does it reach us by convection because the air getting heat from the fire place does not move in all directions. Hot air moves upward from the fireplace.

Heat from the fireplace reaches us directly by the different process in the form of waves called radiations.

Radiation can be stoped:

A sheet of paper or cardboard kept in the path of radiations stop these waves to reach us.

The factors on which rate of emitted radiations depend:

Radiations are emitted by all bodies. The rate at which radiations are emitted depends upon various factors such as.

- Colour and texture of the surface
- Surface temperature.
- Surface area

Radiation process related with objects in a room:

All the objects, lying inside a room including the walls, roof and floor of the room are radiating heat.

However, they are also absorbing heat at the same time.

Radiating of heat through objects:

When temperature of an object is higher than its surroundings then it is radiating more heat than it is absorbing. As a result, its temperature goes on decreasing till it becomes equal to its surroundings.

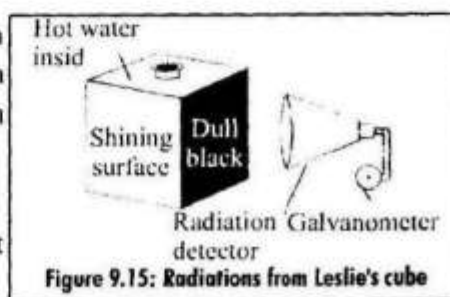
At this stage, the body is giving out the amount of heat equal to the amount of heat it is absorbing.

Absorption of heat in objects:

When temperature of an object is lower than its surroundings, then it is radiating less heat than it is absorbing. As a result, its temperature goes on increasing till it becomes equal to its surroundings.

Figure 9.15: Radiations from Leslie's cube

Importance of nature of the surface in radiation:

The rate at which various surfaces emit heat depends upon the nature of the surface.

Various surfaces can be compared using Leslie's cube.

Q.10.How emission and absorption of radiation can be explained?

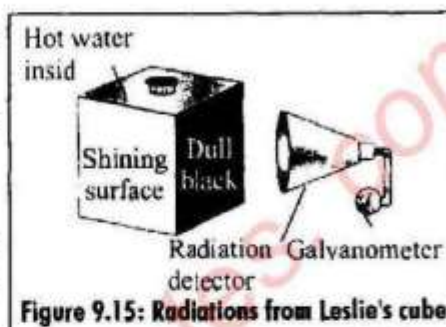
Ans: To explain the emission and absorption of radiation can be compared and explained by using Leslie cube.

Leslie cube: A Leslie cube is a metal box having faces of different nature as shown in given figure.

- A shining silvered surface
- A dull black surface
- A white surface
- A coloured surface

Figure 9.15: Radiations from Leslie's cube

Black dull surface is a good emitter of heat:

Hot water is filled in the Leslie's cube and is placed with one of its face towards a radiation detector.

It is found that black dull surface is a good emitter of heat.

The surface which absorbs more heat: The rate at which various surfaces absorb heat also depends upon the nature of those surfaces.

Explanation: Which surface can absorb more heat can be explained as:

Take two surfaces, one is dull black and the other is a silver polished surface as shown in figure with a candle at the middle of the surface.

Figure 9.16: A comparison of absorption of radiation

Black surface is a good absorber: A dull black surface is a good absorber of heat as its temperature rises rapidly.

A polished surface is a poor absorber:

A polished surface is poor absorber of heat as its temperature rises very slowly.

The given table shows which surface is best absorber, emitter or reflector.

Surfaces	Emitter	Absorber	Reflector
dull black surface	best	best	worst
coloured surface	good	good	bad
White surface	bad	bad	good
shining silvered surface	worst	worst	best

Relation of surface area with radiation: Transfer of heat by radiation is also affected by the surface area of the body emitting or absorbing heat.

Larger is the area, greater will be the transfer of heat. It is due to this reason that large numbers of slots are made in radiators to increase their surface area.

Q.11. Write a detailed note on greenhouse effect.

Ans: (1) Greenhouse: Greenhouse is a house formed by the glass and transparent

polythene sheets. It is used for the better growth of some plants.

Working of Greenhouse:

Figure 9.17: Greenhouse

Light from the Sun contains thermal radiations (infrared) of long wavelengths as well as light and ultraviolet radiations of short wavelengths. Glass and transparent polythene sheets allow radiations of short wavelength to pass through easily but not long wavelengths of thermal radiations. Thus, a greenhouse becomes a heat trap. Radiations from the Sun pass easily through glass and warms up the objects in the greenhouse. These objects and plants give out radiation of much longer wavelengths. Glass and transparent polythene sheets such as shown in figure do not allow them to escape out easily and are reflected back in the greenhouse. This maintains the inside temperature of the greenhouse. Greenhouse effect promises better growth of some plants.

Greenhouse effect in atmosphere: Carbon dioxide and water also behave in a similar way to radiations as glass or polythene.

Figure 9.18: Greenhouse effect in global warming

Greenhouse compounds in Earth's atmosphere: Earth's atmosphere contains carbon dioxide and water vapours. It causes greenhouse effect as shown in figure. Thus maintains the temperature of the Earth.

Increasing temperature of Earth by carbondioxide: (Global warming):

During the recent years, the percentage of carbon dioxide has been increased considerably. This has caused an increase in the average temperature of the Earth by trapping more heat due to greenhouse effect.

This phenomenon is known as global warming.

This has serious implications for global climate.

9.5 Application and Consequences of Radiation

Q.12. What are the application and consequences of radiation?

Ans: Different objects absorb different amounts of heat radiations falling upon them reflecting the remaining part.

Importance of nature and colour of surface:

The amount of heat absorbed by a body depends upon the colour and nature of its surface.

A black and rough surface absorbs more heat than a white or polished surface. Since good absorbers are also good radiators of heat.

Black surfaces of objects: A black coloured body gets hot quickly absorbing heat reaching it during a sunny day and also cools down quickly by giving out its heat to its surroundings. So, the bottoms of cooking pots are made black to increase the absorption of heat from fire.

Heat radiations obey laws of reflection:

The amount of heat reflected from an object depends upon its colour and nature of surface.

Reflection of white surfaces:

White surfaces reflect more than coloured or black surfaces.

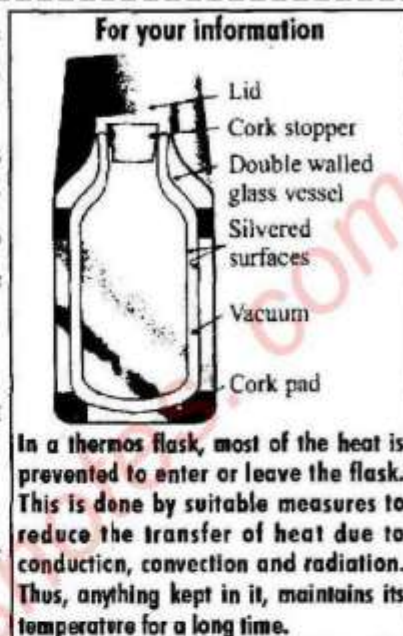
Reflection of polished surfaces:

Polished surfaces are good reflectors than rough surfaces and reflection of heat radiations is greater from polished surfaces.

For your information

In a thermos flask, most of the heat is prevented to enter or leave the flask. This is done by suitable measures to reduce the transfer of heat due to conduction, convection and radiation. Thus, anything kept in it, maintains its temperature for a long time.

Clothes of light colours: We wear white or light coloured clothes in summer which reflect most of the heat radiation reaching us during the hot day.

Cooking pots use reflection process: Interior of the cooking pots are polished for reflecting back most of the heat radiation within them.

SUMMARY

- Heat flows from a body at higher temperature to a body at lower temperature.
- There are three ways of heat transfer. These are conduction, convection and radiation.
- The mode of transfer of heat by vibrating atoms and free electrons in solids from hotter to colder part of a body is called conduction of heat.
- The amount of heat that flows in unit time is called the rate of flow of heat.
- The rate at which heat flows through solids depends on the cross-sectional area of the solid, length between hot and cold ends, temperature difference between hot and cold ends and nature of the material.
- The rate of flow of heat across the opposite faces of a metre cube maintained at a difference of 1 K is called the thermal conductivity of the material of the cube.
- Good conductors are used for quick transfer of heat. Thus cookers, cooking plate, boiler, radiators and condensers of refrigerators etc. are made of metals.
- Water is a poor conductor of heat.
- Materials which trap air are also bad conductors such as wool, felt, fur, feathers,

polystyrenes and fibre glass.

- Transfer of heat by actual movement of molecules from hot place to a cold place is known as convection.
- Land and sea breezes are also the examples of convection.
- Gliders use upward movement of hot air currents due to convection of heat. Air currents help them to stay in air for a long period.
- Birds are able to fly for hours without flapping their wings due to the upward movement of air currents.
- The term radiation means the continual emission of energy from the surface of a body in the form of electro-magnetic waves.
- Radiations are emitted by all bodies. The rate at which radiations are emitted depends on various factors such as colour and texture of the surface, temperature and surface area.
- A dull black surface is a good absorber of heat as its temperature rises rapidly.
- A polished surface is poor absorber of heat as its temperature rises very slowly.
- Radiations from the Sun pass easily through glass/polythene and warms up the materials inside a greenhouse. The radiations given out by them are of much longer wavelengths. Glass/polythene does not allow them to escape out and thus maintains the inside temperature of the greenhouse.
- Earth's atmosphere contains carbon dioxide and water vapours. It causes greenhouse effect and thus retains the temperature of the Earth.
- The bottoms of cooking pots are made black to increase the absorption of heat from fire.
- White surfaces reflect more heat than coloured or black surfaces. Similarly, polished surfaces are good reflectors than rough surfaces and reflection of heat radiations is greater from polished surfaces. Therefore, We wear white or light coloured clothes in summer.
- We polish the interior of the cooking pots for reflecting back most of the heat radiation inside the hot pots.
- A thermos flask consists of a double-walled glass vessel. It reduces the transfer of heat by conduction, convection and radiation.

SOLVED QUESTIONS

9.1 Encircle the correct answer from the given choices:

(i) In solids, heat is transferred by:

(a) Radiation (b) Conduction (c) Convection (d) Absorption

(ii) What happens to the thermal conductivity of a wall if its thickness is doubled?

(a) Becomes double (b) Remains the same

(c) Becomes half (d) Becomes one fourth

(iii) Metals are good conductors of heat due to the:

(a) free electrons (b) big size of their molecules
(c) small size of their molecules (d) rapid vibrations of their atoms

(iv) In gases, heat is mainly transferred by:

(a) Molecular collision (b) Conduction (c) Convection (d) Radiation

(v) Convection of heat is the process of heat transfer due to the:

(a) random motion of molecules (b) downward movement of molecules
(c) upward movement of molecules (d) free movement of molecules

(vi) False ceiling is done to:

(a) lower the height of ceiling (b) keep the roof clean
(c) cool the room (d) insulate the ceiling

(vii) Rooms are heated using gas heaters by:

(a) Conduction only (b) Convection and radiation
(c) Radiation only (d) Convection only

(viii) Land breeze blows from

(a) Sea to land during night (b) Sea to land during the day
(c) Land to sea during night (d) Land to sea during the day

(ix) Which of the folllowing is a good radiator of heat?

(a) A shining silvered surface (b) A dull black surface
(c) A white surface (d) A green coloured surface

Ans: 1. Conduction 2. Becomes half 3. free electrons
4. Convection 5. upward movement of molecules 6. insulate the ceiling
7. Convection and radiation 8. Land to sea during night 9. A white surface

9.2 Why are metals good conductors of heat?

Ans: Metals are good conductors of heat because metal contains free electrons which can move from one place to another, by getting energy.

At the hot end, they get energy from the hot flame and move towards cold end, transferring energy to the other atoms and electron by collision on their way. At the same time atoms at the hot end, start vibrating more vigorously and transfer some energy by collision to neighbouring atoms, eventually heating the other end.

9.3 Explain why:

(a) A metal feels colder to touch than wood kept in a cold place?

(b) Land breeze blows from land towards sea?

(c) Double walled glass vessel is used in thermos flask?

(d) Deserts soon get hot during the day and soon get cold after sunset?

Ans: (a) A metal feels colder to touch than wood because it is a good conductor due to

free electrons.

So it cools down more rapidly as compared to wood. Wood is an example of insulator

(b) At night, the land cools faster than the sea.

Therefore, air above the sea is warmer, rises up and colder air from the land begins to move towards the sea.

(c) Double walled glass vessel is used in thermosflask because double walled glass vessel has air between two glass walls that provide insulation.

(d) Deserts soon get hot during the day and soon get cold after sunset because sand in the deserts has very low value of specific heat.

It cools down and warms up fastly.

9.4 Why conduction of heat does not take place in gases?

Ans: Conduction is the process of transfer of heat by vibrating atoms and free electrons in solids from hotter to colder parts of the body while convection is the process of transfer of heat by actual movement of molecules from hot place to cold place. So in the gases, molecules do not vibrate at their places, due to weak intermolecular forces, the molecules actually move from their places.

Thats way the conduction of heat does not take place in gases.

9.5 What measures do you suggest to conserve energy in houses?

Ans: Energy in houses can be conserved by using energy savers instead of bulbs.

- Switch off the electric appliances when these are not used by humans.
- Geothermal energy can be used to heat up, water into steam for the utilization of cooking food.
- Solar energy is used by solar panel in houses.
  The solar energy is converted into electric energy.
- The bottoms of cooking pots are made black to increase the absorption of heat from fire.
- Hot water tanks are insulated by plastic or foam lagging.
- Wall cavities are filled with plastic foam or wool.
- False ceiling is done using insulating materials.
- Double glazed window panes are used. These window panes have air between glass sheets that provides insulation.

9.6 Why does transfer of heat in fluids take place by convection?

Ans: Convection is a process of transfer of heat by actual movement of molecules from hot place to a cold place. As we know the intermolecular forces are less in fluids as compared to solid, due to weak intermolecular forces the fluids molecules can move from their actual positions and are responsible for the transfer of heat by convection process.

9.7 What is meant by convection current?

Ans: The path flow or current which is used for the transfer of heat by actual movement of molecules for hot place to a cold place is known as convection current.

9.8 Suggest a simple activity to show convection of heat in gases not given in the book.

Ans: An example of convection in daily life is when we use a fire place to heat our home, as the fire heats up the air in front of it, the hot air rises up as it is less dense and than in turn pushes the cool air down so that it is heated and then rises, this motion is called convection currents and is the reason why fire place air effective to heat us.

9.9 How does heat reach us from the Sun?

Ans: Heat reaches us from the Sun through radiation process.

9.10 How various surfaces can be compared by a Leslie cube?

Ans: A Lesile cube is a metal box having faces of different nature.

- A shining silvered surface
- A dull black surface
- A white surface
- A coloured surface

- Black dull surface is a good emitter of heat.
- A dull black surface is a good absorber of heat as its temperature rises rapidly.
- A polished surface is poor absorber of heat as its temperature rises very slowly.
- Larger is the area, greater will be the transfer of heat.

9.11 What is greenhouse effect?

Ans: In the environment, carbondioxide and water also behave in a similar way to radiations as glass or polythene. Glass and transparent polythene sheets allow radiations of short wavelengths to pass through easily but not long wavelengths of thermal radiations. Thus, a green-house becomes a heat trap. Radiations from the Sun pass easily through glass and warms up the objects in a greenhouse. The objects and plants in greenhouse give out radiation of much longer wavelengths and do no allow them to escape out easily and are reflected back in the greenhouse. Similarly Earth's atmosphere contains carbondioxide and water vapours. It causes greenhouse effect and thus maintains the temperature of the earth.

9.12 Explain the impact of greenhouse effect in global warming.

Ans: During the recent years, the percentage of carbon dioxide has been increased considerably. This has caused an increase in the average temperature of the Earth by trapping more heat due to greenhouse effect. This phenomenon is known as global warming.

This has serious implications for global climate.

SOLVED PROBLEMS

9.1 ***The concrete roof of a house of thickness 20 cm has an area 200 m². The temperature inside the house is 15°C and outside is 35°C. Find the rate at which thermal energy will be conducted through the roof. The value of k for concrete is 0.65 Wm⁻¹K⁻¹.***

Data: Thickness $= L = 20\text{cm} = \frac{20}{100} = 0.2 \text{ m}$

Area $= A = 200\text{m}^2$

Outside temperature $= T_1 = 35°C$

$T_1 = 35 + 273$

$T_1 = 308 \text{ K}$

Inside temperature $= T_2 = 15°C$

$T_2 = 15 + 273$

$T_2 = 288 \text{ K}$

Value of k of concrete $= k = 0.65 \text{ Wm}^{-1}\text{K}^{-1}$

To Find out: Rate at which thermal energy is conducting $\frac{Q}{t} = ?$

Formula: $\frac{Q}{t} = \frac{kA(T_1 - T_2)}{L}$

Solution: Rate at which thermal energy is conducting $= \frac{kA(T_1 - T_2)}{L}$

By putting all given values $= \frac{(0.65)(200)(308 - 288)}{0.2}$

$= \frac{(130)(20)}{0.2} = \frac{2600}{0.2}$

Rate at which thermal energy is conduction $= 13000 \text{ Js}^{-1}$

$$\boxed{\frac{Q}{t} = 13000 \text{ Js}^{-1}}$$

Answer: The rate at which thermal energy is conducting is 13000 Js^{-1}.

9.2 ***How much heat is lost in an hour through a glass window measuring 2.0 m by 2.5 m when inside temperature is 25°C and that of outside is 5°C, the thickness of glass is 0.8 cm and the value of k for glass is 0.8 Wm⁻¹K⁻¹?***

Data: Time $= t = 1 \text{ hour} = 60 \times 60 = 3600 \text{ sec}$

Area $= 2.0\text{m} \times 2.5\text{ m} = 5\text{m}^2$

Temperature inside the room $= T_1 = 25°C$

$T_1 = 25°C + 273$

$T_1 = 298 \text{ K}$

Temperature outside the room $= T_2 = 5°C$

$T_2 = 5 + 273$

$T_2 = 278 \text{ K}$

Thickness of glass $= L = 0.8 \text{ cm}$

$= \frac{0.8}{100} = 0.008 \text{ m}$

The value of k for glass $= 0.8 \text{ Wm}^{-1}\text{K}^{-1}$

Amount of heat lost = Q = ?

Formula: $\frac{Q}{t} = \frac{kA(T_1 - T_2)}{L}$

Solution: By putting the values in given formula:

$$Q = \frac{t\ k\ A(T_2 - T_1)}{L}$$

$$= \frac{(3600)(0.8)(5)(278 - 298)}{0.008}$$

$$Q = \frac{(14,400)(-20)}{0.008}$$

$$Q = -36000000$$

$$Q = -36 \times 10^6$$

$$Q = -3.6 \times 10 \times 10^6$$

$$Q = -3.6 \times 10^7$$

$$\boxed{Q = -3.6 \times 10^7 \text{ J}}$$

Her. – ve sign, shows the lost of heat.

Answer: The required heat lost in an hour through a glass window is 3.6×10^7J.

OBJECTIVE TYPE QUESTIONS (MCQ'S+SHORT ANSWER) FROM PREVIOUS ANNUAL PAPERS OF ALL SECONDARY BOARDS (LAHORE, GUJRANWALA, FAISALABAD, MULTAN, SAHIWAL, SARGODHA, RAWALPINDI, D.G. KHAN And BAHAWALPUR)

9.1+9.2 Transfer of Heat+Conduction

☆ **Tick the correct answer.**

1. **If thickness of a wall is doubled, then its thermal conductivity becomes:** (GRW. GI, SWL. GI, GRW. GI, FBD. GII)
   (A) double (B) remains the same (C) half (D) one fourth
2. **The example of bad conductor is:** (GRW. GII)
   (A) wool (B) copper (C) gold (D) iron
3. **Metals are good conductor of heat due to the:** (MLN. GII)
   (A) Free electrons (B) Big size of their molecules
   (C) Small size of their molecules (D) Rapid vibrations of their atoms
4. **False ceiling is done to:** (SGD. GII, MLN. GII)
   (A) Lower the height of ceiling (B) Keep the roof clean
   (C) Cool the room (D) Insulate the ceiling
5. **The thermal conductivity of dry air is ______ $Wm^{-1}K^{-1}$:** (DGK. GII)
   (A) 0.08 (B) 0.03 (C) 0.2 (D) 0.026
6. **The Thermal Conductivity of Silver is ______ $Wm^{-1}K^{-1}$:** (BWP. GI)
   (A) 430 (B) 400 (C) 245 (D) 105
7. **In solids heat is transferred by:** (LHR. GII, DGK. GII, RWP. GII)
   (A) Radiation (B) Convection
   (C) Conduction (D) Convection and radiation
8. **Example of a bed conductor is:** (GRW. GII)
   (A) wool (B) gold (C) iron (D) graphite
9. **Poor conductor of heat is:** (SWL. GI)
   (A) copper (B) aluminium (C) water (D) iron

Answers

1. half 2. wool 3. Free electrons 4. Insulate the ceiling
5. 0.026 6. 430 7. Conduction 8. wool 9. water

☆ **Give short answer to the following questions.**

1. **What is transfer of heat? Write the names of its method.** (LHR. GI, FBD. GII)

Ans. Transfer of heat: When two bodies at different temperature are in thermal contact with each other. Thermal energy from a hot body flows to the cold body in the form of heat.

This is called as transfer of the heat.

Ways of heat transfer: There are three ways by which transfer of heat takes place.

1. Conduction 2. Convection 3. Radiation

2. **Define thermal conductivity.** (LHR. GII, MLN. GI)

Ans. Thermal Conductivity: Thermal conductivity of a substance can be defined as;

The rate of flow of heat across the opposite faces of a metre cube of a substance maintained at a temperature difference of one kelvin.

3. **Why metals are good conductors of heat?** (GRW. GI & GII, DGK. GI, MLN. GII)

Ans. Metals are good conductors of heat because metal contains free electrons which can move from one place to another, by getting energy.

4. **Why conduction of heat does not take place in gases?** (FBD. GII, DGK. GI & GII, BWP. GI)

Ans. Conduction is the process of transfer of heat by vibrating atoms and free electrons in solids from hotter to colder parts of the body while convection is the process of transfer of heat by actual movement of molecules from hot place to cold place. So in the gases, molecules do not vibrate at their places, due to weak intermolecular forces, the molecules actually move from their places.

Thats way the conduction of heat does not take place in gases.

5. **Define the rate of Flow of Heat.** (MLN. GI)

Ans. Rate of flow of heat: The amount of heat flows in unit time is called the rate of flow of heat.

Rate of flow of heat $= \frac{Q}{t}$

6. **Define Radiation.** (MLN. GI)

Ans. Radiation: Radiation is the mode of transfer of heat from one place to another in the form of waves called electromagnetic waves.

7. **On what factors the rate of heat flow in solids depends?** (MLN. GII)

Ans. The rate of heat flow in solids depends upon the following factors.

1. Cross-sectional area of the solid.
2. Length of the solid.
3. Temperature difference between ends.

8. **What is meant by conduction?** (SGD. GI, RWP. GII, SWL. GII, DGK. GII)

Ans. Conduction: The mode of transfer of heat by vibrating atoms and free electrons in solids from hot to cold parts of a body is called conduction of heat.

9. **Write the uses of Conductors and Non-Conductors.** (DGK. GII, RWP. GI, SGD. GI)

Ans. Uses of conductors:

- Good conductors are used when quick transfer of heat is required through a body.
- Cookers, cooking plate, boiler, radiators and condensers of refrigerators, etc. are made of metals such as aluminium and copper for the better conduction.
- Metal boxes are used for making ice, ice cream, etc.
- Sauce pans are made of metal for quick heat transfer.

Uses of non-conductors:

- Insulators or bad conductors are used in home utensils such as handles of sauce-pans, hot plates, spoons etc. They are made up of wood or plastic.
- Air is one of the bad conductors or best insulator.

That is why cavity walls i.e two walls separated by an air space and double glazed windows keep the houses warm in winter and cool in summer.

10. **Describe the effect of length on thermal conductivity.** (LHR. GI & GII)

Ans. Effect of length on thermal conductivity:

Larger is the length between the hot and cold ends of the solid, more time it will take

to conduct heat to the colder end and smaller will be the rate of flow of heat, Thsu

Rate of flow of heat $\propto \frac{1}{L}$

11. Write two uses of non-conductors. (MLN. GI, SGD. GII)

Ans. Uses of non-conductors:

- Insulators or bad conductors are used in home utensils such as handles of sauce-pans, hot plates, spoons etc. They are made up of wood or plastic.
- Air is one of the bad conductors or best insulator.
  That is why cavity walls i.e two walls separated by an air space and double glazed windows keep the houses warm in winter and cool in summer.

9.3+9.4 Convection+Radiation

9.5 Application and Consequences of Radiation

☆ Tick the correct answer.

1. In gases, heat is mainly transferred by: (LHR. GI, RWP. GI, SGD. GI)
(A) Molecular collision (B) Conduction (C) Convection (D) Radiation

2. Rooms are heated using gas heaters by: (LHR. GII, FBD. GI, SGD. GII)
(A) Only conduction (B) Radiation
(C) Convection (D) Radiation and convection

3. The glider ramains in air due to: (FBD. GII)
(A) Power (B) Conduction (C) Radiation (D) Convection

4. Land and sea breezes are result of: (SWL. GI & GII, BWP. GII)
(A) conduction (B) convection (C) radiation (D) absorption

5. Which of the following birds are expert Thermal Climbers? (BWP. GI)
(A) Eagles (B) Hawks (C) Vultures (D) All these

6. _______ is good radiator of heat. (MLN. GI)
(A) A shining silvered surface (B) A dull black surface
(C) A white surface (D) A green coloured surface

7. The surfaces of Leslie's Cube are: (MLN. GI)
(A) 1 (B) 2 (C) 3 (D) 4

8. Worst absorber of heat is: (DGK. GI)
(A) Dull black surface (B) Coloured surface
(C) White surface (D) Shining silvered surface

9. Which surface is bad emitter: (BWP. GII)
(A) White Surface (B) Black Surface
(C) Coloured Surface (D) Silver Surface

Answers

1.	Convection	2.	Radiation and convection	3.	Convection
4.	convection	5.	All these	6.	A shining silvered surface
7.	4	8.	Shining silvered surface	9.	Silver Surface

☆ Give short answer to the following questions.

1. Differentiate between land breeze and sea breeze. (LHR. GII, DGK. GII)

Ans. Sea breeze: On a hot day, the temperature of the land increases more quickly than the sea. It is because the specific heat of land is much smaller as compared to water.

The air above land gets hot and rise up. The cold air from the sea begins to move towards the land.

Land breeze: At night, the land cools faster than the sea. Therefore, air above the sea is warmer, rises up and the colder air from the land begins to move towards the sea as shown in given figure. It is called land breeze.

2. **What is meant by convection current?** (GRW. GI & GII, RWP. GI, SWL. GI, BWP. GII, MLN. GII)

Ans. Convection Current: The path flow or current which is used for the transfer of heat by actual movement of molecules for hot place to a cold place is known as convection current.

3. **Describe use of convection currents.** (SWL. GI & GII, FBD. GI, BWP. GI)

Ans. Uses of convection currents:

Convection currents occur on a large scale in nature. Some uses of convection currents are as;

- Convection currents set up by electric, gas or coal heaters help to warm our homes and offices.
- Central heating systems in buildings work on the same principle by convection.
- The day-to-day temperature changes in the atmosphere result from the circulation of warm or cold air that travels across the region.
- Land and sea breezes are also the examples of convection current.

4. **What causes a glider to remain in air?** (SGD. GI, RWP. GI, SWL. GII, DGK. GII)

Ans. The upward movement of air currents in thermals help gliders to stay in air for a long period.

5. **Why land breez blows from land towards sea?** (DGK. GI)

Ans. Land breez blows from land towards sea, because at night, the land cools faster than the sea. Therefore, air above the sea is warmer, rises up and the colder air from the land begins to move towards the sea.

6. **Why does transfer of Heat in fluids take place by Convection?** (BWP. GI, GRW. GI)

Ans. Convection is a process of transfer of heat by actual movement of molecules from hot place to a cold place. As we know the intermolecular forces are less in fluids as compared to solid, due to weak intermolecular forces the fluids molecules can move from their actual positions and are responsible for the transfer of heat by convection process.

7. **Differentiate between conduction and convection.** (FBD. GI)

Ans. Conduction: The mode of transfer of heat by vibrating atoms and free electrons in solids from hot to cold parts of a body is called conduction of heat.

Convection: Transfer of heat by actual movement of molecules from hot place to a cold place is known as convection.

8. **What is meant by land breeze?** (FBD. GII)

Ans. Land breeze: At night, the land cools faster than the sea. Therefore, air above the sea is warmer, rises up and the colder air from the land begins to move towards the sea. It is called land breeze.

9. **What is meant by convection?** (SGD. GII)

Ans. Convection: Transfer of heat by actual movement of molecules from hot place to a cold place is known as convection.

10. Why is not advisable to wear dark colours in summer? (LHR. GI)

Ans. It is not advised to wear dark colours in summer, because dark colours absorb more radiations and heat.

11. What is the scientific reason to wear white and light coloured clothes in summer? (FBD. GI)

Ans. We wear white or light coloured clothes in summer which reflect most of the heat radiation reaching us during the hot day.

12. Write down the names of four surfaces of Laselie Cube. (SGD. GII, RWP. GII)

Ans. 1. A shining silvered surface
2. A dull black surface
3. A white surface
4. A coloured surface

13. On what factors Radiation depends? (LHR. GII)

Ans. The factors on which radiations depends.

☆ Colour and texture of the surface ☆ Surface temperature ☆ Surface area.

14. Write two consequences of radiation. (GRW. GII)

Ans. 1. We wear white or light coloured clothes in summer which reflect most of the heat radiation reaching us during the hot day.
2. Interior of the cooking pots are polished for reflecting back most of the heat radiation within them.

15. Describe relation of radiation of heat and surface area. (FBD. GII)

Ans. Relation of surface area with radiation:

Transfer of heat by radiation is also affected by the surface area of the body emitting or absorbing heat.

Larger is the area, greater will be the transfer of heat. It is due to this reason that large numbers of slots are made in radiators to increase their surface area.

16. How does heat reach us from the sun? (DGK. GI)

Ans. Heat reaches us from the sun through radiation process.

17. What is thermos flask? (GRW. GI)

Ans. Thermos flask: In a thermos flask, most of the heat is prevented to enter or leave the flask. This is done by suitable measures to reduce the transfer of heat due to conduction, convection and radiation. Thus, anything kept in it, maintains its temperature for a long time.

18. Explain the impacts of Greenhouse Effect in Global warming. (MLN. GII, BWP. GII)

Ans. During the recent years, the percentage of carbon dioxide has been increased considerably. This has caused an increase in the average temperature of the Earth by trapping more heat due to greenhouse effect. This phenomenon is known as global warming.

This has serious implications for global climate.

19. What is greenhouse effect? (SWL. GI & GII, LHR. GI, FBD. GI)

Ans. Greenhouse effect: In the environment, carbondioxide and water also behave in a similar way to radiations as glass or polythene. They allow radiations of short wavelengths to pass through easily but not long wavelengths of thermal radiations. Thus, a green-house becomes a heat trap. It causes greenhouse effect and thus maintains the temperature of the earth.